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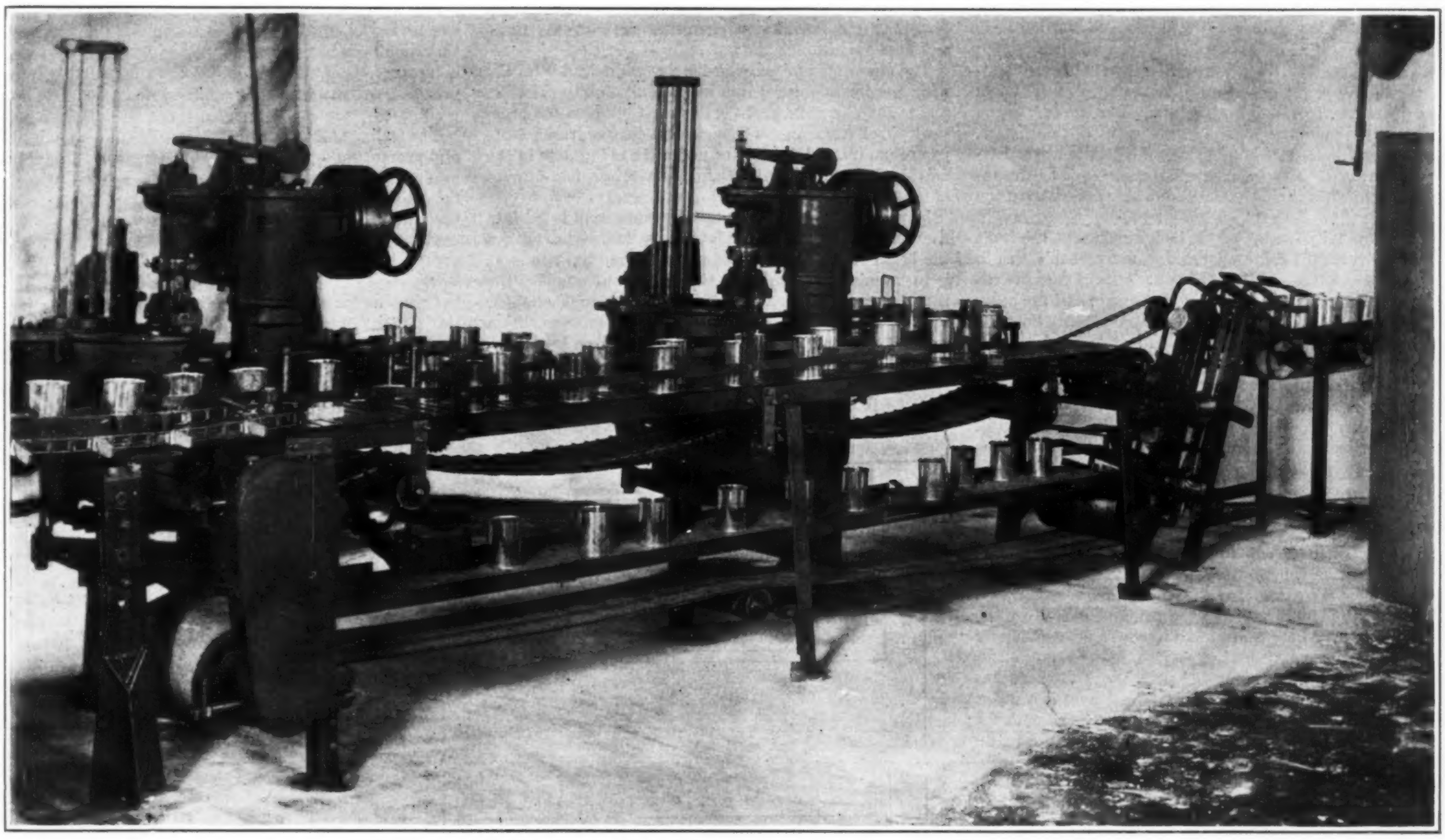


The "Sanitary Cans" are sealed in this machine by means of a solderless crimped joint.

A row of kettles in the preserve-making plant.

THE SCIENTIFIC ADVANCEMENT OF THE CANNING INDUSTRY.—[See page 40.]

Handling White Lead

A Sanitary Mechanical System for Eliminating Dust from Operations with Dry Material

A COMPLETE system for the safe handling of white lead from the drying pans until it leaves the chaser as lead-in-oil paste, has been perfected, and is now being regularly operated. From the sanitary standpoint, this is the most notable improvement made in lead manufacturing since the early days of white lead manufacture in America when inclosed machinery was substituted for hand labor in separating the white lead from the scraps of metallic lead which had failed to corrode.

The perspective view (Fig. 1) illustrates this mechanical system. A battery of inclosed drying pans is shown on the upper floor, and on the lower floor the rest of the equipment including weighing apparatus and a chaser, both inclosed in dust-proof covering. In the upper left-hand corner of Fig. 1 is a cross-section view of the inclosure showing the battery of four pans, one above the other.

A noteworthy feature of the inclosure is that the front has two vertical partitions, both provided with doors to give access to each individual pan. One of these partitions is placed close to the front of the pan, and the other forms the outside of the housing. The distance between these partitions is amply sufficient to allow the dry white lead from the pans to drop into a screw conveyor at the bottom of the space between the two vertical partitions.

Referring to the construction of the individual pans it is to be noted that the front of each pan instead of being vertical has a gradual upward and outward slope, which permits the removal of the contents of the pan with a hoe instead of a shovel. The cross-section view shows how the hoe is used in drawing lead out of the pans. The lead simply falls between the two partitions, as already explained, and into the screw conveyor. The same operation is illustrated in the perspective view at a point where a portion of the front appears broken away. The lead thus removed from the pan is delivered by the screw conveyor into the inclosed dry-lead storage hopper on the floor below.

Before coming to the drying pans the white lead has been ground, sifted and washed. This leaves it a water paste, and it is in this form that it reaches the pans for drying. Three features of the drying operations are: (1) the double bottom of the pans through which steam passes, supplying the heat; (2) the circulation of air over the tops of the pans to absorb and carry off the moisture from the drying lead; (3) control of any dust which may arise as the drying process goes on.

Dust control and the circulation of air for drying purposes are secured as follows. (See Fig. 2). At one end of the inclosure a suction fan is mounted, suitably inclosed. The suction chamber connects through dampers with the spaces above each pan. The continuous operation of the fan maintains a partial vacuum throughout the pan inclosure. Through the openings marked "air inlet" a current of air is admitted which flows between the bottom of the lowest pan and the floor along the entire length of the pan battery. On its way it absorbs heat from the bottom of the lowest pan, and thus increases its power to take up moisture from the lead. When the air reaches the chamber at the far end of the inclosure, it divides and passes back over the tops of the four pans to the chamber beneath the fan housing at the end where it started, and the fan draws the moisture-laden air out into the atmosphere. This is the regular course of operation.

But when the lead on a pan has become thoroughly dry, and it is necessary to unload the pan, the air inlet and damper connecting the space above that particular pan with the fan chamber are shut. The outer and inner doors in front of that pan are then opened to permit the removal of the lead. Immediately on opening the doors, the suction in the space opened creates an in-draft of air. This current of air picks up such dust as arises when the lead is hoed out of the pan and when the lead falls between the partitions to the screw conveyor. The air, bearing dust in suspension, flows to the air-distributing chamber at the remote end of the inclosure. From the disturbing chamber the air current divides and passes over the three other rows of pans of the battery. But the current, being now spread throughout three spaces, moves so much more slowly than it did when confined in one space that practically all of the suspended dust is deposited on the surfaces of the other three rows of pans. Reaching the fan-suction chamber, the currents unite and pass out through the fan.

The operation of removing the dry white lead from the pans has by this apparatus become absolutely safe. It makes the pan room and the discharging operation practically free from dust. The normal temperature of the pan room, instead of being as under the old system in the neighborhood of 100 deg. Fahr., is within a few degrees of the temperature of the rest of the factory.

From the storage hopper the dry white lead is fed into the weigh hopper below, which also is dust tight. When the beam of the scales shows that as much has run in as is to be mixed at one time, the feed is cut off. By the movement of a lever, the contents of the weigh hopper are fed into a short-screw conveyor which connects with a series of chasers. One of the chasers is shown in the immediate foreground of Fig. 1. By opening a damper in the pipe, connecting the screw conveyor with the chaser, the lead is allowed to fall within the inclosed, dust-proof hood of the chaser. There it is mixed with oil in the proper proportion. After the lead and oil are thoroughly incorporated a small gate at the bottom is opened and the mixture passes in the form of white-lead paste to the feed tube of the mills on the floor beneath. There it gets a final grinding and is delivered as the white-lead-in-oil paste of commerce. While all the joints through this system are made as air-tight as possible, it will be noticed that an air-suction tube is connected to the apparatus as a further precaution. In a word, so far as the drying process goes, the danger of poisoning from dust has been eliminated.

The feeling is that as this system safe-guards the health and promotes the welfare of the workingman it should be used as widely as possible. The plans are therefore given this publicity, details can be furnished to any manufacturer wishing to put these plans into operation.

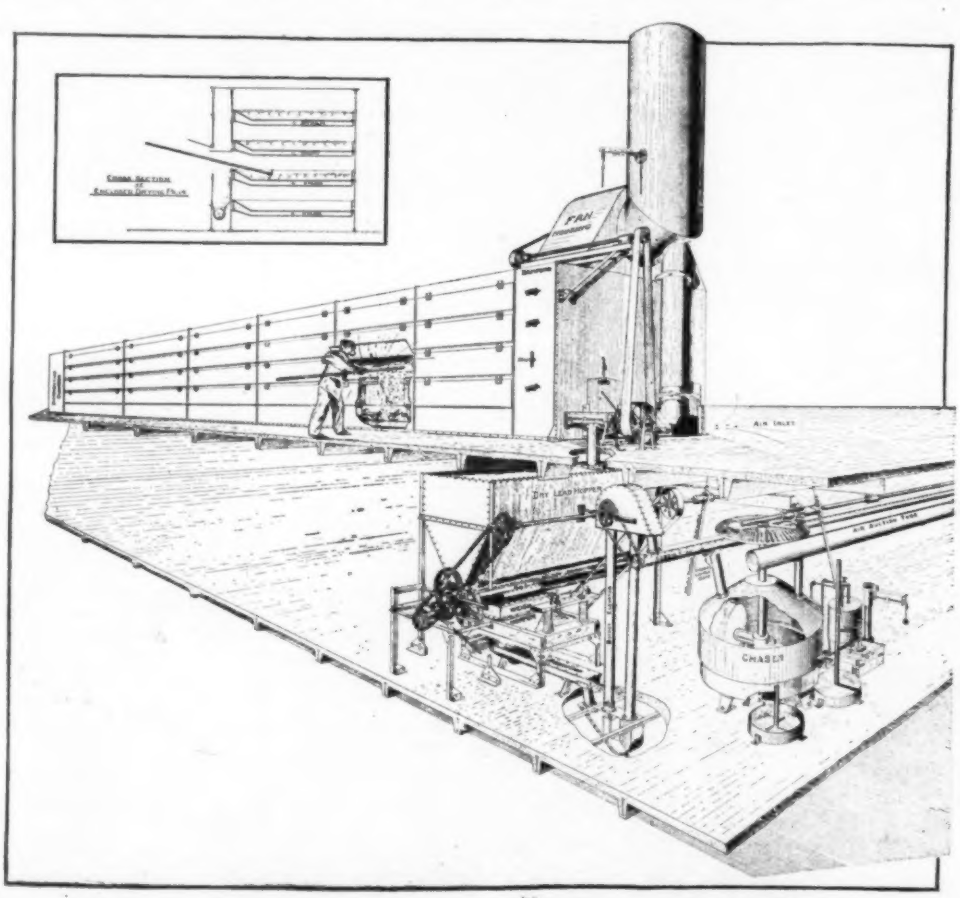


Fig. 1.—Sanitary mechanical system for drying and dustless handling of white lead.

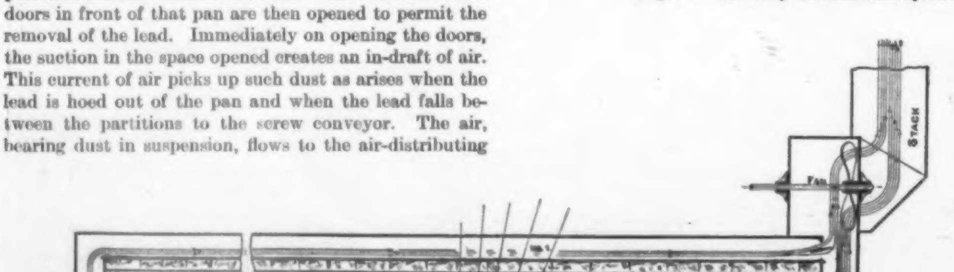


Fig. 2.—Longitudinal section of drying pans, showing air currents while discharging at door No. 3.

Coal in the Antarctic

CONCERNING the discovery of coal in the Antarctic regions visited by the Shackleton and Scott expeditions, Prof. D. W. Edgeworth David, professor of geology and physical geography in the University of Sydney, is quoted in the Australian press as saying: "In reference to the scientific discoveries of Scott's party there can be no doubt they will prove of immense interest and importance. In the first place it is stated that a good collection has been obtained of fossil plants associated with the seams of coal discovered by Shackleton at Buckley's Island, at the head of the Beardmore Glacier. Frank Wild, of Shackleton's party, was the actual discoverer of seven seams of coal outcropping in a great cliff face of sandstone and shale. The thickness of these seams was 7 feet, inclusive of a few clay bands, and Wild chopped small specimens of the coal out with his ice axe. These have been analyzed in Sydney and show the coal to be of workable quality. It is almost certain that this coal field will prove to be perhaps one of the largest of the unworked coal fields of the world, as it has been traced now through the further researches of Capt. Scott's geologists, Messrs. Griffith, Taylor, and F. Debenham, to a point about 650 miles north of the Beardmore Glacier."—*Chemical Engineer.*

Aerial Battleships and Flying Torpedo Boats

German Dirigibles versus French Aeroplanes

When, on the third of April, at about one o'clock in the afternoon, a huge German dirigible, the "Zeppelin IV.," of 20,000 cubic meters capacity, suddenly appeared above the parade ground of the French fortress of Luneville and then slowly came to earth, the event naturally gave a sharp shock to the French Government; and it was hardly less embarrassing to the German Government. On the one hand there was seen the grim potentiality of menace, while, on the other hand, there was the danger of important secrets of construction falling into the hands of a possible enemy, and the awkwardness of the situation from a diplomatic point of view. The occurrence has lent fresh zest to the lively interest taken both by the army and by the general public in the question of the comparative value in actual warfare of a fleet of dirigibles and one of aeroplanes.

With enterprising briskness the French magazine, *Lecture Pour Tous*, published in its May number a discussion of the arguments involved and the statements made by various distinguished airmen when interviewed by M. Ch. Torquet.

Germany has devoted most time, money, and skilled research to the development of the various types of the dirigible; France, to that of the aeroplane, or *avion*, in all its forms.

M. Torquet says: "The Germans put all their confidence in the dirigibles. Their first care has been given to the construction of the hangars, which are the ports of the balloons. To avoid the difficulty of entering the shed which may be caused by a high wind, they have constructed orientable hangars which can be turned so as to lie 'in the eye of the wind.' Most of these are floating, which makes them cheaper. Some of them are constructed on a turntable, but this is a very costly type. Others, of a most ingenious type, consist of a deep trench covered by a roof which rises at one end, working with a jaw-like action. Ascent is made with great readiness and expedition from this style of hangar.

"These hangars are so located as to line the seaboard and the east and west frontiers of Germany. Others guard the capital.

"The Zeppelins extant at the present time are one at Koenigsberg, one at Frankfort, one at Metz (this one could be in France in nine minutes after the declaration of war), and one at Strasburg. Two are being repaired and one is being built. (The 'Sachsen,' now completed, is stationed at Leipzig.) We may add two semi-rigids without much military value, and four flexible Parsevals at Koenigsberg, Potsdam, Breslau and Metz—twelve in all; a number which will doubtless be doubled by the end of 1913."

M. Torquet here gives a detailed statement of the French dirigibles, with the concluding statement: "Hence, at the end of the present year, we shall have only eleven large 'cruisers' to oppose to the twenty-four owned by the Germans. The thirteen others for which funds have been voted and whose gas capacity will total 30,000 cubic meters, cannot be ready until 1914."

A similar comparison as to aeroplanes and trained pilots shows France to be much superior to Germany in this direction; and it is also stated that though the French machines are frailer looking, they are much better constructed than the German ones, which are still too heavy, while the air-cooled rotary motor is also better than the heavy water-cooled German motor.

Obviously, then, in case of war there would be a contest between German dirigibles and French aeroplanes—battleships and torpedo boats. Gen. Lacroix frankly avows his belief in the superiority of the dirigible. Col. Estienne, however, advises even greater concentration on the aeroplane branch of air service, and the provision of whole fleets of these of different types, light ones for scouting and heavy armed ones for direct combat and destruction.

M. Le Hérissé, an important member of the parliamentary commission of inquiry, said, when interviewed:

"Each instrument has different qualities. They are equally necessary. Certainly dirigibles '*sacrificed beforehand*' can achieve brilliant '*coups*,' but they are valuable above all for strategic reconnaissance on a large scale. For this purpose rapid cruisers, capable of making 85 kilometers (52¾ miles) per hour are best.

"But the dirigible is only a medium of transit. In good weather, without too strong a wind, a Zeppelin can stay aloft for 25 hours if need be and travel a distance of 900 kilometers (559 miles)."

The Cologne hangars are but 450 kilometers from London, so that given a speed of 75 kilometers (46½ miles) an hour, London, Portsmouth, and the British arsenals might be reached and returned from in a single night.

"The dirigible," continued M. Hérissé, "will collect all the strategic information capable of being gathered at night; the movement of trains and position of fleets, location of stores and of points of disembarkment for troops, etc. It carries a powerful wireless instrument, which keeps it in constant communication with headquarters. If the balloon fails to return, at least the information gleaned will be saved.

"And will its sacrifice permit it to destroy some important possession of the enemy?

"No. Certainly a large dirigible carrying easily 1,000 kilogrammes (about a ton) of projectiles and a crew of ten, can attack and destroy military hangars, magazines, powder-works, and railroad switches. But the technicians will tell you that although it alone possesses the precious power of stopping and remaining stationary above a given point, and of launching a projectile with perfect accuracy, it can do no damage to such works as tunnels and bridges. . . . The latter, whether of stone or iron, need fear explosives only when carefully applied at a chosen spot to act with a maximum of violence against a pier or main girder.

"And we must not forget the grave defects of the dirigible. In cloudy weather, in order to make observations, it would have to descend to 700 meters (2,300 feet) altitude. Only at this height is it possible to distinguish with any accuracy between cavalry, infantry, artillery, etc.

"But the huge target (the dirigible) does not begin to be safe below 2,000 meters (6,560 feet). Lower, it is highly vulnerable, and though ordinary field cannon do not carry farther than 600 meters in the air, the arms of the infantry are still dangerous at 1,400 meters, while the new high-angle, rapid-fire guns can destroy any dirigible which ventures below the 3,500 meters (11,480 feet) of their range."

M. Marc Doussand, when interviewed, expressed himself in favor of the avion for a number of *psychological* reasons.

"It is," he said, "the *French*, or rather the *Latin*, instrument, which best responds to our temperament and our peculiar qualities. The Germans have only anonymous "bodies" or "corps"; we have *men*. Individuals, dare-devils, we possess *decision*, that *Latin reflex* which causes us to make the necessary movement before we have calculated it. This reflex is everything in aviation, and they haven't got it in Germany. Attentive and serious, they reflect maturely upon the action demanded, by which time the moment for it is long past. I don't say they're not brave, patient and obstinate. They kill a man a day and still fly badly."

In the battle of "pygmies against a giant" M. Marc Doussand thinks the foremer, i. e., the avions, from their number, speed, and comparative invulnerability, would have great advantages. He acknowledges the inferior sphere of action of the avion, but comments on its cheapness and ease of repair, while a dirigible costs some $170,000 and requires months to repair.

The famous naval aviator, André Beaumont, thinks the lightness of the French aeroplanes an advantage. He said: "Heaviness is not solidity. What is needed is light aeroplanes solidly constructed of the best materials. The German avions are heavy, run 300 meters before lifting and need 300 meters in which to land."

He concludes his remarks by saying: "To all our criticisms of dirigibles the Germans reply that they apply only to flexible balloons, not to their famous rigid frames. In these the fourteen independent compartments enable them to remain aloft even if one compartment has been burst. . . . But though the machine might stay aloft, it would be destroyed eventually, having lost a notable part of its ascensional force and its responsiveness to the rudder.

"It would very soon be obliged to descend. On the ground, not being capable of instant deflating, like the flexible, by the pull of a cord, it would be dragged an indefinite length and soon destroyed by natural obstacles or by the enemy."

M. Spiess, the inventor of the first rigid balloon ordered by the French army, whose frame is of wood instead of aluminium, considers the flexible balloons quite worthless. The points in favor of the "rigid" are that it performs its evolutions more readily; can not burst, since the gas is not under pressure (being contained in ballonets); and rises higher than its weaker rival by means of its own dynamic power.

An interviewer remarked that on the ground, the rigid dirigible was more fragile. The inventor treated this remark with calm contempt, thinking it sufficiently answered by pointing out that the commercial company which runs a line of Zeppelins for passenger traffic has made nearly 200 consecutive trips with the "Victoria-Luise" without the slightest accident.

Production of Aluminium

At the present time France produces as much aluminium as Austria, Germany, and Russia together, and comes, from this point of view, immediately after the United States.

The following table (in tons) drawn up in 1911 by M. Trillot, on the occasion of the International Exhibition, of Liège, is a proof of this assertion:

Years.	France.	England.	Central Europe.	United States.	Total.
1899	800	600	1,600	5,000	8,000
1900	1,000	600	2,500	3,200	7,300
1901	1,200	600	2,500	3,200	7,500
1902	1,400	600	2,500	3,300	7,800
1903	1,600	700	2,500	3,100	8,200
1904	1,700	700	3,000	3,700	9,300
1905	3,000	1,000	3,000	4,500	11,500
1906	4,000	1,000	3,500	6,000	14,500
1907	7,000	2,500	4,500	7,000	21,000

For 1911 the total production of France reached 14,700 tons, and the production of the whole world 32,000 tons at the most. The advance of France has then been largely kept up during the last four years.

The regular increase of this production may be considered as quite remarkable when it is remembered that in 1878 France produced only 1 ton of aluminium. It is true that in 1857 the works installed at Nanterre under the direction of Sainte-Claire Deville had been able to put out 600 kilogrammes at 97 per cent of pureness; but the metal which contained 2.7 of iron and 0.3 of silica was unfit for the industrial uses such as they are understood to-day. It was, then, the year 1878 which saw the real birth of the modern industry of aluminium.

At any rate, in 1800, the world's consumption reached 1,500 kilogrammes, produced by the one French manufactory of Salindres. From 1886, when the purely chemical methods were abandoned for the electrolytic method, the production went on increasing gradually, and in 1896 reached 1,755 tons.

Not less interesting is the descending progression in the sale price. Until about 1856 the kilogramme of aluminium cost from 900 to 1,000 francs. The works of Sainte-Claire Deville quickly reduced its market value to 300 francs per kilogramme, and this price has since then continually decreased as the manufacture was improved.

It was only 100 francs in 1885, when the adoption of electrolytic processes precipitated the lowering of its price, which was only 80 francs in 1886, and fell to 25 francs in 1887; in 1888 to 15 francs, in 1892 to 12 francs.

According to a reliable statistic, the variations it has undergone since then are the following:

	Price per ton, £.
1892	495
1896	163
1901	130
1905	130—170
1907	200—106
1908	100— 65

The average price per kilogramme, which was 2.60 francs in 1900, passed to 3.25 francs in 1901 to fall to 2.80 francs in 1903, rising again to about 4.70 francs in 1907, but in 1908 it was only 2.15 francs. At the end of 1908 the price of the kilogramme even went considerably beneath 2 francs.

This progression has not stopped, and there is every reason to believe that it will not be stopped for some time to come. But it is not only in France that this progress is to be noticed; according to a recent official publication, the United States have increased their extraction of bauxite from 149,932 tons in 1910 to 155,618 tons in 1911, with a global value of 3,900,000 francs, being an increase of 178,800 francs on the preceding year.

These figures show how artificial was the crisis of 1908-1909, and they show how great is the ever increasing prosperity of the young and great industry which produces metallic aluminium.—*Chemical News.*

Fig. 1.—Bad yard conditions.
(In cases like this, the inside conditions in the plant are likely to be bad also.)

Fig. 2.—Defective steel framework, supporting a heavy hoist.
(Severe Corrosion. The bolt heads could be pulled off with the fingers.)

Safety Engineering*

A Study of Its Broad Principles Should Form Part of Every Engineering Course

By G. Gilmour

The prevention of industrial accidents is a problem worthy of the most serious consideration. For many years' past, in European countries, a careful study has been made of the conditions which lead to such accidents, and the dangerous features of the various trades have been minimized as far as possible, and in some cases almost entirely eliminated. Manufacturers and other extensive employers of labor in our own country have been slow to recognize their duties to their employees in this respect, but the subject of accident prevention has been taken up recently, with a good deal of zest, by insurance companies, engineering societies, federal and State governments, and business corporations, and quite a good deal of real progress has been made. The materialistic spirit still holds a firm grip on society and the individual, however, and I fear that there is thus far no universal realization of the fact that the lives and welfare of the so-called working classes are of greater importance than increased factory production or extra dividends.

ACCIDENT STATISTICS.

It is generally admitted that a great waste of human energy is caused by accidents connected with industrial activities. There are no official statistics from which the losses due to the industrial accidents of the United States can be calculated; but the admittedly incomplete data that are obtainable show very clearly that there is room for vast improvement in promoting the safety and welfare of the workers. A conservative authority has estimated that the number of fatal vocational accidents to adult male workmen in this country, each year, is between 30,000 and 35,000. In addition to this enormous death rate, we probably have 2,000,000 non-fatal but more or less serious accidents, which cause a tremendous amount of suffering, and no doubt effect a considerable reduction in the average length of life among the masses who are exposed to these accidents. The figures given above, enormous as they seem, apply only to the adult males that are employed in industrial work regularly and steadily. They do not include the accidents that befall the great number of temporary workers in industrial plants, nor do they include the working women, of whom there are some six million in the United States. They also exclude the thousands of workers who are minors, and the multitudes of children who, I regret to say, are employed in American factories and so-called sweat shops. If all these various classes were included, I believe we should find that the number of deaths from industrial accidents in the United States reaches the enormous figure of 50,000 per annum.

* Reproduced from *The Travelers Standard*.

CLASSES OF ACCIDENTS.

Industrial accidents may be divided into two main classes, which, although the boundary between them is occasionally hard to fix, are usually fairly well separable. The first class consists of the *unavoidable* accidents, that is, those that cannot be foreseen, or which cannot be prevented by any practicable means. The second class comprises the accidents that are due to carelessness or ignorance, or to the neglect, by the employer or the employee or both, of reasonable precautions, or to various other curable causes that I need not enumerate in full.

Although the absence of statistics makes it impossible to determine the relative magnitude of these two classes, in our own country, with anything like precision, we may nevertheless form some approximate idea of the subject by studying the records of other countries where statistics of industrial accidents are kept, and by obtaining from employers and liability insurance companies the figures that they may have compiled along this line, in the course of their business activities.

Germany is the nation to which we most naturally look for information of this kind, because she is foremost, thus far, in all matters pertaining to accident prevention; and Germany has found that in her various industries taken collectively, 58 per cent of the accidents that occur clearly belong to the preventable class, while 42 per cent are considered to be unavoidable consequences of the hazards that naturally pertain to the work. In other words, more than half of her industrial accidents could be eliminated, if employer and employee exercised the greatest possible care in the performance of the work.

An illuminating comparison with the foregoing figures is afforded by the following specific case, taken from American practice: In a certain industrial establishment where the number of accidents had previously averaged 200 per annum, rules were drawn up and safety methods and devices were introduced, with the result that during the following year the number of accidents dropped to 64, and 38 of these 64 belonged to the unavoidable class, because it was impossible to foresee or prevent them. These figures, when compared with the average of 200 accidents that characterized previous years, indicate that only about 20 per cent of the accidents that occurred before the change was made could be classed as unavoidable. In other words, it was found possible to prevent about 80 per cent of the accidents that had occurred in this particular industry, by studying the conditions carefully, and taking intelligent measures to guard against sources of danger that could be recognized, and could be neutralized by practicable methods. This shows what a large and important field of action is open to the technical man, or engineer, who has the necessary knowledge of the subject of safety engineering; for the conditions that prevailed in the plant I have just cited were in no wise peculiar, and they did not

Fig. 3.—A box of steel shearings, about to be carried over the heads of the workmen by a traveling crane.

Fig. 4.—Defective flooring along a much-used passageway. The loose screens in the middle distance lie over large floor holes.

Fig. 5.—An unguarded belt drive for a wood planer.
(The belts run at high speed.)

Fig. 6.—A properly railed belt drive for a wood planer.
(A heavy plank shield, not shown, is set in front of the open space.)

differ in any essential respect from those that prevail to-day in hundreds of other plants.

NEED OF SPECIALLY TRAINED MEN.

The situation that I have outlined calls loudly for a remedy, and it is our duty to consider the matter carefully, and see where the remedy is to be found. Many are of the opinion that what we need is more laws, and it is likely that something quite helpful could be accomplished in this way if the laws could be framed by persons thoroughly informed with regard to the facts and the practicability of suggested remedies. We cannot cure the trouble by laws alone, however. To cope with the situation properly we need, most of all, a greater number of specially trained men.

Many engineers who occupy responsible positions in industrial plants have given no thought to the dangers associated with the work, and have acquired no special knowledge or experience, to aid them in protecting the lives and limbs of the workers. These engineers may be highly competent, so far as technical requirements in connection with manufacturing and production are concerned, and yet wofully deficient when judged by their ability to safeguard the lives and conserve the earning powers of those who do the great bulk of the constructive work that makes the business pay. This is all wrong. I think it is fair to charge our colleges and technical schools with a certain share of responsibility for it, because in their study of engineering they give little or no attention to safety, and sometimes it is not even mentioned, in the entire four years. A study of the broad general principles of safety engineering should be included in all engineering courses, and subjects that relate to accident prevention should have at least an equal standing with those that relate to efficiency.

There is no doubt whatever about the great economic loss that a community has to bear, by reason of the injuries that its workers receive in following out their daily labors; and the progressive business man should hail with special approbation any work that may be done, to reduce the loss and waste that these injuries entail. He ought to feel sympathy enough for the worker to actively assist in any reasonable measures for his relief, for humanitarian reasons alone; but if he cannot do this, then he should lend his support because the economic welfare of his shop, his town, his State, and his country, demands it.

In Europe the position of safety engineer is an honored one, to which young men aspire, and for which they train themselves, and which they are glad to take up as a career. Why may we not have it so here, to a vastly greater extent than now?

THE CAUSES OF ACCIDENTS.

The causes of industrial accidents have only recently been systematically studied in the United States. This is to be regretted, because a thorough understanding of the subject of causation must be had, before we can deal intelligently with the problem of accident prevention. It has been assumed, quite generally, that industrial accidents are chiefly attributable to the absence of safety-devices, around dangerous machines or in other places where danger is known to exist; but closer examination has shown that a wider view of the subject must be taken than this, and that we must recognize many other causes also, notably the following: Ignorance, carelessness, unsuitable clothing, poor lighting, ill-conducted and crowded work-places, and defects in machines and buildings. Poor ventilation should be added, as an important but secondary cause, because bad air in a work-room dulls the sensibilities of the employees, and induces a drowsiness which makes the men indifferent to the dangers that surround them. Unreasonably long working hours will produce the same effect, and so also will the use of alcoholic drinks during the day.

IGNORANCE.

I have given ignorance the dubious prestige of first rank in the list of causes, and to avoid misunderstanding I wish to say that I use the word not as necessarily implying a lack of *intelligence*, but mainly as signifying mere absence of knowledge about the sources of danger that are present, or the ways in which these sources should be minimized or avoided. The ignorance that leads to accident is not displayed exclusively by the workman, although he is usually the one who suffers. Ignorance regarding efficient safety devices is all too often as marked in the highest official as it is in the unskilled laborer. The employees should be given complete and detailed instructions regarding their work, and emphasis should be laid upon the dangerous features connected with the various operations. Special care should be given to apprentices and newly employed men in this respect. Attention should be directed not only

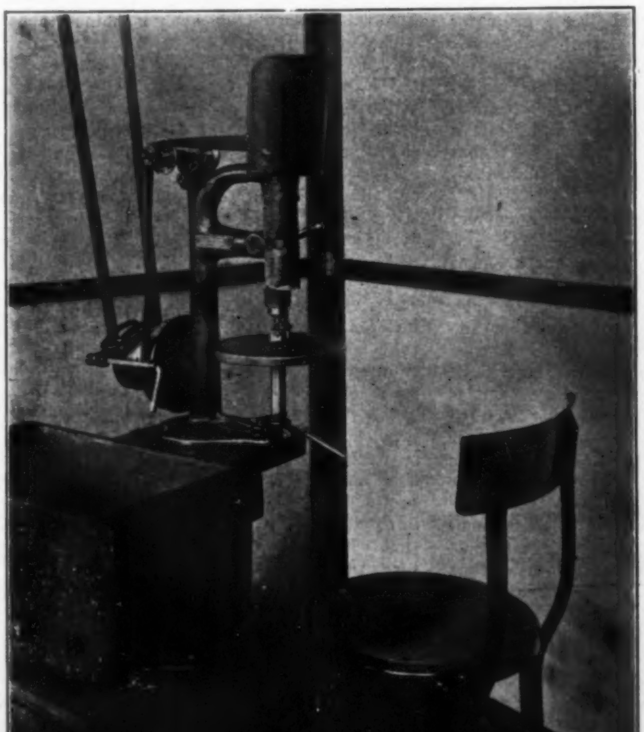


Fig. 7.—A guarded spindle belt.
(Note the shield in front of the spindle, to protect the operator's head in case the belt breaks.)

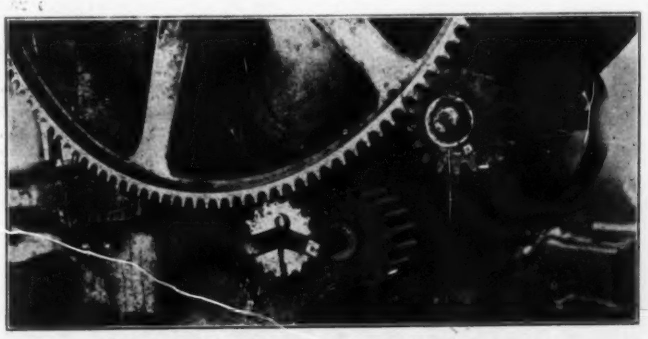


Fig. 8.—Bad gearing on a heavy foundry crane.
(The pinion teeth are nearly gone. The gears should also be covered.)

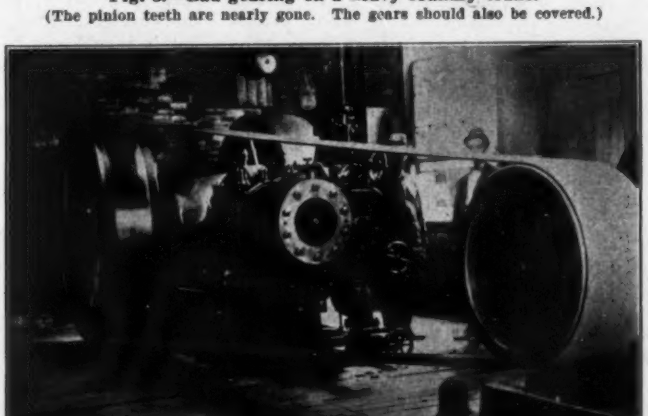


Fig. 9.—An unguarded belt drive.
(Men often pass through belts of this kind, though the practice is highly dangerous. The belt should be guarded on both sides, and the guard should include the driving wheel and the pulley.)

to the dangers incident to each individual's particular employment, but also to the hazardous conditions in his immediate vicinity, even if such conditions do not directly concern the work assigned to him. Particular attention should be given to the methods that are used for issuing instructions with regard to safety precautions, on account of the numerous nationalities that may be represented among the workmen. It should be remembered that some of them may not have the slightest knowledge of the English language. Innumerable accidents have been due to the simple fact that the workmen did not understand the instructions given by their foremen. In every case of this kind the foreman should be held responsible, and he should never allow the men to work at dangerous machines nor in dangerous places until he has assured himself that his instructions have been made clear. All printed directions and instructions should be transcribed in several languages, when this appears to be desirable on account of the various nationalities represented among the employees. Competent interpreters should also be provided, to explain these various matters orally; because it is likely that some of the men cannot read the language that they speak.

Whenever a man is transferred from one department to another, or is required to operate a machine of a different kind from that to which he has been accustomed, he should be fully instructed in his new duties, and warned of any dangers that may be associated with unfamiliar operations connected with them.

When workmen are operating certain kinds of intrinsically dangerous machines, it is often desirable to instruct them to place themselves in special positions, so that if any part of the machine should break, or if accidents of any other nature should occur, the chances of injury will be reduced to a minimum. There are many plants, also, in which certain of the operations should be intrusted only to men of known intelligence and discretion. These should be selected with care, for if men with dulled faculties or insufficient training are permitted to undertake operations of this kind, a considerable number of accidents may be expected to ensue.

CARELESSNESS.

Carelessness is the cause of a great many of the so-called avoidable accidents, and it sometimes takes the form of recklessness, although it is more often manifested as mere thoughtlessness or indifference. The workman should be thoroughly impressed with the fact that when he is engaged in work of a hazardous nature, or when he is operating a dangerous piece of machinery, his safety depends, to a large extent, on his own careful consideration of the possible result of every movement. When he has learned the motions that may be safely used in performing the work upon which he is engaged, they soon become instinctive, and a false move will serve to warn him of danger. A workman who repeatedly receives injuries while performing the same kind of work should be given employment of a less dangerous nature. He should even be dismissed, if necessary, because he is a poor moral hazard, and he exerts a dangerous influence upon his fellow employees. A careless workman cannot count upon receiving the same consideration from his fellow workers as a careful one.

CLOTHING.

Unsuitable clothing is the cause of numerous accidents, many of which are serious. The moving parts of machines (especially rotating parts) cannot always be completely covered in, and a workman may easily be caught in the mechanism if he wears an unbuttoned coat, or one with a torn or ragged sleeve. Many fatal accidents, from such causes, have occurred in connection with rotating machines that look more or less harmless.

When women are employed to operate machines, or are at work in close proximity to transmission lines or to other machinery, we have to consider another risk which is somewhat akin to that arising from defective clothing. A number of frightful accidents have occurred by the *hair* being drawn into rotating machinery, or wound up on it. The simplest way to prevent such accidents would be for the women to keep their heads covered by hoods of some kind, which would completely protect the hair during working hours. I doubt very much, however, if employers in general would be successful in introducing such a remedy. Women often consider their hair to be one of their chief ornaments, and regard it as birds do their plumage. Personally, I should be reluctant to depend very much upon strict compliance with any regulation that required the hair to be completely inclosed. It would no doubt be safer to see that all revolving machinery and transmission lines are protected so thoroughly that the hair cannot become caught in them.

POOR LIGHTING.

The causes of accident that I have considered, thus far, are those which may be obviated, at least to a great extent, by the adoption of ordinary precautions by the employees, although, as has been stated, the employer should see that necessary warnings and instructions are provided in all cases. I will pass, now, to causes the cure of which rests solely or mainly with the employer; and defective or insufficient illumination is the first item of this general class to suggest itself, as it is one of the most prolific sources of accidents.

It is well known that industrial accidents are most numerous during the winter months, when a sensible fraction of the work is performed either by the aid of artificial illumination, or by weak daylight; and this shows the great importance of giving attention to the lighting problem.

When using artificial illumination, the arrangement of the lights is often very poor. This is particularly noticeable in machine shops, where the illumination provided for a machine tool often consists of an incandescent electric lamp placed close to the tool, and partly screened to prevent it from shining strongly and directly into the eyes of the workman. The illumination is concentrated, in this way, upon the tool and the work, and the other moving parts of the machine are left in comparative obscurity. It is easy to see that such an arrangement almost invites accident.

The workman has a right to expect a sufficient amount of light, properly distributed; and it is quite practicable to give it to him without prohibitive expense, by using lamps that are adapted to the work, and locating them in accordance with a proper plan.

The lamp shades or reflectors should be kept clean, and the windows of the shop should be frequently washed, so that they will not obstruct the entrance of daylight. Ceilings and walls should be covered with white paint, or be whitewashed, because this treatment is of great assistance in making the rooms light, and it thus aids in preventing many of the accidents that are likely to occur in dark working places.

ILL-CONDITIONED WORKPLACES.

Ill-conditioned and unsanitary working places often impair the health of the employees, and hence they may be properly classed among the indirect causes of accidents. Every reasonable precaution should be taken to insure good sanitary conditions. This is a duty that the employer owes to his help, without regard to its profitableness; but it is also worth noting that expenditures made for this purpose are excellent investments, not only because they tend to reduce the obvious loss of efficiency that comes from sickness among skilled operators, but also because the average workman will undoubtedly exercise more care, and show a higher productivity in his work, if he feels that his comfort and welfare receive reasonable attention from his employer.

In many shops and factories that are beyond reproach so far as sanitary conditions are concerned, the arrangement of the machines is a source of danger. This is a matter of fundamental importance, and it gives the safety engineer a good opportunity to show his judgment regarding the hazards involved, and his care for the safety of the workmen. Economy of floor space is important, but it should not be carried too far, because it is always supremely important for the workmen to have space enough to move freely about their machines, without danger. For example, it is almost imperative that there should be a clear passageway at least two feet wide between the table of a traveling planer, when it is at the end of its travel, and the wall or the next machine. It is also important to arrange the planer so that its table does not travel over a passageway, particularly if the passageway is used for transporting trucks or other heavy objects.

Passageways and gangways should never be crowded with material over which someone is likely to stumble, and rails that are laid for trucks should not be allowed to project above the floor level.

Defects in machines and buildings are highly important, and yet they cause a relatively small proportion of the total number of accidents, because they are too closely associated with the production to be long overlooked by the employer or the engineer.

AGE OF EMPLOYEES AS RELATED TO ACCIDENTS.

I may here speak of a phase of the accident problem which is quite important, and concerning which there is apparently a general misapprehension. It is often assumed that the likelihood of accident increases as the workmen grow older, and many employers are therefore unwilling to engage the services of middle aged or elderly men. This idea is without any sound foundation. Sir John Brunner has carried out careful investigations covering a period of fifteen years, and has found that there is an actual *decrease* in accidents, with advancing age. The frequency of accidents among workmen under thirty years of age, for example, is greater than among men who have passed that limit. It was shown that the frequency of accidents among workmen between the ages of 18 and 25 years is from three to four times as great as it is in the age class exceeding 56 years. It is true that among men of the younger class there were many apprentices or beginners, and who, therefore, had less experience and knowledge regarding the dangers connected with their occupations; but even in the class including those from 25 to 30 years of age, the frequency of accidents was nearly three times as great as in the class above 51 years. The reduction in the number of accidents in the higher age classes is partly due, without doubt, to the fact that the older men were employed on less hazardous work; but the greater part of the difference is certainly due to the greater experience of the older men, and to the exercise, by them, of greater caution. At all events, Brunner's investigations show that there is no reason for the manufacturer to refuse employment to older men on account of any assumed greater liability to accidents. Nor should an employer discriminate against an older man from a purely productive point of view, because a workman who is exercising care with regard to his own personal safety will also, as a rule, handle his machine in such a manner that breakdowns will be avoided; and consequently he may contribute an equal amount to the output of the plant, even though his working capacity may be somewhat below that of the younger man.

SAFETY DEVICES.

We will return, now, to the subject of safety devices, and to the widely prevalent belief that the installation of appropriate devices of this kind is all there is to safety engineering. This view, of course, is altogether erroneous. Safety devices are not magical things, that can transform danger into absolute safety as the philosopher's stone of olden days was supposed to transmute lead into pure gold. They are highly important, however, and their intelligent application is a matter for serious study. We must not underrate the dangers connected with badly designed machines, nor the perils involved in permitting such machines to be operated, year after year, with no safety devices, or with devices that are unsuitable and inefficient.

Without doubt, the proper time to make provision for safety devices is when the machines are being laid out in the draughting room, and it should be the first duty of a machine designer to see that all possible protection is given to the lives and limbs of the operators of his machines. It is gratifying to note that both designers and manufacturers are coming to realize this important fact, and it is common, nowadays, to meet with newly manufactured machines whereon all the dangerous parts, such as gears, wheels, and belts, are perfectly inclosed or guarded. This shows that the interest that is taken in accident prevention all over the country has already had an important influence on machine design, from the safety point of view.

The designer can take care of the safeguard problems in the cheapest and best way, while he is working out the details of the machine; and if a machine is built without giving any thought to its safe operation, it is difficult and sometimes impossible to add, afterward, any safety device that will effectively prevent accidents to the operator. In machine design, safety of operation should be considered as important as mechanical efficiency, and our technical schools and colleges could hardly do a better service to the industries of the country, than by impressing this fact upon the students, and educating them accordingly.

I have often met with cases in which employers were willing to do everything possible to provide safety devices for the protection of the workmen in their plants, but where it has been impossible to accomplish much in this way for the reason that the design of the buildings or the machinery did not permit the introduction of such devices. In many instances traveling cranes are found without protective railings, and with no possibility of

building such railings, on account of the small clearance between the cranes and the roof of the building. If the safety question had been considered when the cranes were installed, it is probable that they could have been safeguarded at a trifling increase in cost, and with no loss in efficiency. Generally speaking, whether it is a question of building construction or of the manufacture of a machine, if provision for safety devices is considered at the very commencement of the design, the cost of the structure or the machine will be affected to only a slight degree, or not at all. I therefore wish to emphasize again the importance of working out all safety devices on the drawing board, and of educating engineers and constructors so that they will fully understand the importance of this feature of design. It is important, furthermore, to remember that machines which cannot be operated without danger to life and limb may be unprofitable, even if they are remarkably efficient in production.

It is quite necessary, in designing and constructing safety devices, to make sure that they are arranged so that the workmen will not purposely remove them from the machines, nor render them inoperative in other ways. Workmen often do these things, particularly if the device interferes in any way with the operation of the machine, or decreases its production to even a slight extent. We are here touching upon one of the most troublesome phases of the safety device problem. The employer is likely to object to any appliance that reduces the output, and the operators are pretty sure to side with him when they are working with such a device on the piece-work system, valuing what they lose from their earnings more than they do the protection to their own persons. Furthermore, safety devices that manifestly do *not* lessen the production nor cut down the wages, are sometimes removed by the operator merely because he is not used to them, or because he takes a baseless and unreasoning dislike to them.

The designer should carefully study all these features of the case, and produce protective devices that will not interfere with the production to any serious extent, and which the operator will not remove, or cannot remove.

Safety appliances should always be made of substantial material, and, as a rule, nothing should be used for them but metal. A metallic netting, built on a substantial frame, often serves better than a sheet-metal guard for the protection of moving parts, because the machinery can then be readily seen and inspected, without removing the guard.

CO-OPERATION OF PURCHASERS NECESSARY.

Prospective purchasers of machinery should cooperate with the safety engineer by refusing to close any contract until it is evident that all possible safeguards have been provided for the various machines that are offered. They will soon realize that properly safeguarded machines are the cheapest in the long run, and that they are important factors in the safe and ininterrupted operation of the plant. Machines are often disabled and rendered unfit for operation for days at a time merely because tools or pieces of clothing or other materials have become caught in unprotected gears or other moving parts, and an adjoining machine is often wrecked, also, as the result of such an accident. These various facts, together with the employer's liability to his workmen in case of accident, should be sufficient to show that efficiency safety devices should always be provided, even if they should slightly increase the cost of the machine at the time of purchase.

SAFETY DEVICES OF A GENERAL NATURE.

I will briefly mention a few safety devices of a more or less general nature, which are applicable to industries of all kinds.

Gear wheels should always be carefully protected, particularly when they are within reach of the floor or when they are in proximity to bearings or other parts of the machinery which require periodical attention. It is quite common to find gears which are only partly covered with hoods, and curiously enough we have come across instances where the inrunning side of the gear has been entirely unprotected, even though the outrunning side, where there is little danger, has been most carefully covered in. It is hard to believe that a man who is at all familiar with any kind of machinery would make such a mistake as this, and I think such cases must be attributed to gross carelessness rather than to lack of knowledge. It is usually best to inclose all of the gearing, but it is particularly important that the inrunning side should always have a substantial covering extending the entire width of the wheels, and overhanging their teeth. It is especially necessary to entirely inclose *reversible* gears, which may rotate in either direction.

Spoked wheels, particularly those which run at high speed, often cause serious accidents by catching the arms or clothing of operators who approach them too closely. They should be entirely inclosed with hoods, and the hoods should be made to cover any projecting key heads that there may be, as these are sometimes highly dangerous. Setscrews on collars or in other places should preferably be of the counterbored type, and be screwed in flush with the surrounding surfaces. If they are left projecting, they should be covered by guard rings or hoods. At the present time the accidents that are caused by exposed set screws are very numerous.

Ends of shafting, projecting over passageways or into places where workmen are likely to be moving about, should be covered by sleeves. Loose clothing is frequently caught by such projecting shafts, particularly when they are running at high speed, and very serious accidents result. Shafting, pulleys, and belts, when located within easy reach of working platforms, should be well guarded by hoods or railings. Belt shifters of a substantial design should always be used for removing and replacing belts. Shifting belts by hand, or by means of detached sticks or poles, is very dangerous. It also involves a considerable loss of time, as the poles are seldom at hand when they are needed, and the men have to hunt them up. Ladders should be dispensed with as far as possible, and when they are used they should not be allowed to rest against revolving shafting. The lower ends of all ladders that are to be used in shops should be provided with spikes or rubber caps or other effective devices of like nature, to prevent them from slipping. Platforms and gangways, when raised above the surrounding levels, should be provided with substantial handrails; and they should also have toe boards, to prevent materials from falling over the edges and dropping upon men who may be below.

Signs and placards giving warning of dangerous conditions should be used wherever they are needed, but they are really nothing but makeshifts. It is always far better to provide an effective protection, than to merely announce the presence of the danger. Shops or factories that are fully placarded with such signs are poorly arranged, as a rule, when considered from the safety engineer's point of view.

ORGANIZING SAFETY DEPARTMENTS.

In industrial plants, and particularly in those of large size, the employer or the chief engineer should organize a safety department under the direction of a good mechanical engineer who has sound judgment and a full knowledge of the hazards that are involved in all the manufacturing processes that are used in the plant. A safety committee should also be organized from the foreman of the various departments, and it should be the business of this committee to study the conditions in the plant, and to submit recommendations for lessening the hazards of the business. Each foreman should be made responsible for his own department, and should see that the men under his charge are thoroughly instructed regarding the dangerous conditions surrounding them. Excellent results can be obtained in this way. The Engineering and Inspection Division of The Travelers Insurance Company, in addition to carrying out inspections and issuing recommendations regarding safety methods and appliances, is often called upon to make recommendations to manufacturers and corporations regarding the organization of safety departments. As an illustration of the results of our work, I may mention that some time ago we made a thorough examination of the conditions existing in all the shops and yards of the Pennsylvania Railroad Company, and then submitted a complete report to the executives of the railroad, dealing with the introduction of safety methods and devices, and suggesting the organization of a safety department. Our recommendations were adopted and carried out by the railroad company, and the number of accidents per annum was thereupon reduced by about 60 per cent.

Life Conservation*

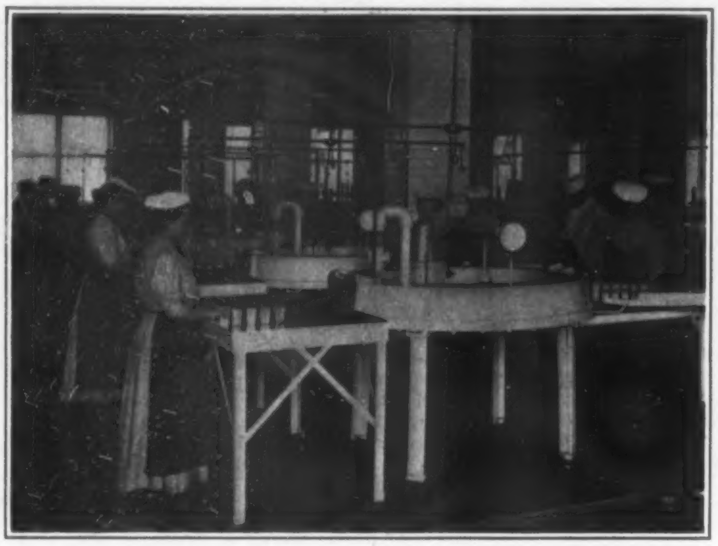
THE paradox has been well put that the most precious thing is the cheapest—in money; while the most useless thing is the dearest—in dollars and cents. The cost of killing a man in modern warfare averages $15,000; in the Boer War it was $40,000. The six great European powers are grinding two billions of dollars out of their respective peoples for military preparations—not for war, it is said, but to prevent war! Meanwhile millions of young men who should be engaged in industrial pursuits are maintained in utterly unprofitable idleness, and are quartered, it is declared, in inadequate and sometimes tuberculosis-ridden barracks. On the other hand, Col. Gorgas and his associates have converted the formerly pestilent and deadly Isthmus of Panama into one of the healthiest regions on earth, at a cost of $2.43 for each life saved. Many hundreds of men, women and children in our South have been cured of the hookworm disease at an average cost of 77 cents for each sufferer. It is indeed true that the most precious thing in nature is human life (and human health by which life is enjoyed and lengthened), and as we have seen, it is about the cheapest; while the most useless and foolish thing is human warfare, which is the most costly.

Irrationality akin to that evinced in Europe, though not so flagrant, has been shown by our House Committee on Indian Affairs in refusing the request of the Secretary of the Interior for adequate funds with which to do hospital sanitation and medical work among the "nation's wards." The appropriation has been $90,000; but investigation revealed conditions much worse than had been supposed. The death-rate from pulmonary tuberculosis in the federal registration area is 11; among the Indians it is 32, while the death-rate of the latter from all causes is 30, or more than double that in the registration area. On ascertaining these facts Secretary Fisher in his annual report recommended that the appropriation for prevention and treatment of disease be increased to $400,000; but the members of our billion-dollar Congress (which had just voted millions to be added to those already given in pensions) balked at such expenditure in behalf of a people for whose welfare our government has very largely assumed the responsibility and whose diseases are constantly endangering their white neighbors.

The conservation of health is perhaps the most important idea which the twentieth century has thus far evolved. Irving Fisher computed that the span of life in the United States could be increased fifteen years if all the hygienic reforms now known were put into effect, and outlined a plan for better health protection by federal, State and municipal governments, with the co-operation of many agencies and movements now benignantly active for the betterment of sanitary and hygienic conditions among our people. The life-insurance companies have taken admirable part, and have conceived a policy of enlightened selfishness, based on the fact that the longer the policy-holder lives, the more premiums he will pay.[1] Mr. Cox of New York, the counsel of the Association of Life-Insurance Presidents, states that out of a total of nearly thirty million policies in force in American companies at the end of 1910, the companies in this association carry about 77 per cent (or over twenty-three million), and of the latter, 97 per cent are in companies now engaged in individual work for health improvement. Five companies within this association (having policies aggregating $22,000,000) make special efforts to stimulate their policy-holders to activity in personal and public hygiene—mostly by articles in company periodicals distributed to policy-holders and by other effective literature. One company has done this for many years. Another co-operates besides with existing anti-tuberculosis and like agencies, for health improvement; this company is experimenting in many cities with visiting nurses to sick policy-holders. Another company has established a department of conservation which is ambitious, among other things, to aid public-health authorities in the fight against preventable disease. This is a tremendous activity indeed, and with plenty of material to work on; for actuaries have estimated that the economic value of lives lost needlessly each year in the United States alone is $1,500,000,000.

* Reproduced from the *Journal* of the American Medical Association.

[1] Cox, R. L.: "Conservation of Human Life," reprinted from "The Business of Insurance by the Association of Life-Insurance Presidents."



White enamel kitchen where cans are sealed in vacuo.

Autoclaves for cooking under pressure.

The Scientific Advancement of the Canning Industry*

A Most Important Contributor to the Modern Provision Market

By R. T. Mohan, M.Sc.

The preserving of foods has its basis in the work of Pasteur (1822–1895), but even 70 years before his researches we have, in 1795, a process invented by a Frenchman, Appert, for preserving foods in hermetically sealed receptacles, and this process was awarded a prize of 16,000 francs by the French government. This process consisted in placing the articles to be preserved in corked receptacles, and then subjecting these to the heat of boiling water for varying lengths of time dependent on the nature of the foods. Naturally this process of Appert was kept as secret as possible, but the information gradually leaked out, and in 1815 was brought from England to America. In 1819 an Englishman named Daggett had a canning factory in New York city, for packing lobster, salmon, and oysters, and in 1825 fruits and vegetables were canned.

In these early days glass jars only were used, but their cost, breakage, etc., led to the use of tin cans, the first patent for which was secured in England in 1823, and in America in 1825. The cans were made in the canning factory, and their manufacture was slow but interesting. The greatest difficulty was experienced in making the tops and bottoms. A weight was pulled up to the ceiling and allowed to drop on a sheet of tin; a die was cast in the under side of the weight, and the opposite die was cast in a piece of metal below. In order to guide the weight so that the dies would strike in the proper place, two upright grooved guides were made, similar to those of a pile driver. The body of the can was made on a cylindrical form, the edges were butted together and soldered, and then the tops and bottoms soldered on.

*Paper read before the Canadian Section of the Society of Chemical Industry, and published in the *Journal* of the Society. The photographs which accompany this article we owe to the courtesy of Dr. A. W. Bitting, of the Bureau of Chemistry, Washington, D. C.

Gradually, however, machinery was developed for can-making, and to-day the process of production of finished cans from sheet tin plate is automatic and continuous,

Retorts for cooking canned goods.

and the industry is entirely separate from that of canning, although many canning companies work their own can-making plants.

In the original Appert process only boiling water was used for sterilization of the foods. This was found insufficent for many products, so, later on, salt was added to the water to raise the boiling point, and this was afterward supplemented by the addition of calcium chloride, so that temperatures up to 240 deg. Fahr. could be produced. In 1874 a Baltimore man invented a closed retort for cooking with superheated steam. This led to our modern retorts or autoclaves, which produce various temperatures from 212 deg. Fahr. up, depending on the steam pressure used.

Although the industry dates back to 1795, it was conducted for a long time entirely without any knowledge of the real scientific principles underlying the methods in use, and it is interesting to look at some of the early theories advanced. The first theory was that of the exclusion of air. This was recognized by Appert, who stated that it was the external air which caused spoilage and not the air in the jar. Guy-Lussac, who was instructed by the French Government to investigate Appert's process, reported that spoilage of food was caused by a series of oxidation changes, and by drawing out the air and preventing its getting in again these oxidations were prevented. This theory that the air must be excluded was followed up to recent times, in evidence of which we see, only a few years ago, that cans were sealed, heated, vented to allow the air to escape, resealed, and then cooked. Sometimes a second heating and venting was given before cooking.

The next theory was the vacuum theory, closely related to the first theory: that is, it was believed to be only necessary to get rid of the air by vacuumizing, and mechanical methods were developed to produce a vacuum. Many losses were experienced by those who blindly accepted this theory, for the vacuum has no real value in preserving foods, except in special instances such as salt meats, peanut butter, jams, etc.

Peas are graded for size in revolving sieves.

Testing cans for leaks.

Removing scales, fins and entrails in one operation.

Recovering values from the waste products. Pea vines are made into silage.

Pasteur was the first to associate spoilage with organisms. Russell, of Wisconsin, was one of the first to apply the theories and methods of Pasteur to the solution of spoilage problems encountered in canning, and in 1895 he showed that spoilage in canned peas was due to the presence of bacteria which had survived an insufficient sterilization. Prescott and Underwood, of Boston, made studies of sour corn, and first explained to the Packers' Association Convention at Buffalo, in 1898, some of the causes for spoilage in canned foods, and they showed slides of bacteria they had isolated from sour corn.

Among the important early investigations on canned foods was the work of the Canadian Government in 1897 on the spoilage of canned lobster. The packers were troubled by so-called "black lobster," and the investigation showed it to be due to bacteria.

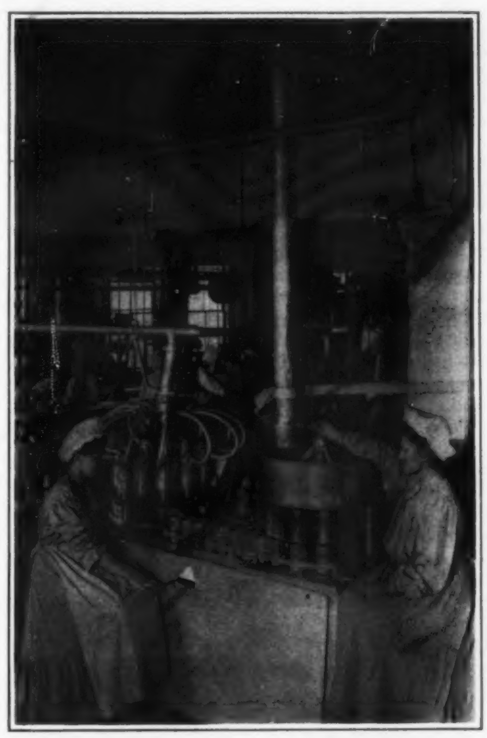
With the introduction of science into the industry the first step was to put the processing or sterilization on a sound basis. This entailed a careful study of the organisms found on fruits and vegetables and in the air. By the introduction of these organisms into good cans the changes produced were noted. The temperatures necessary to kill these organisms were studied. The time necessary for heat to penetrate to the center of cans of food of different consistency was found out. By adding to this time of penetration the time necessary to kill the bacteria the basis of a process was established.

One of the instruments, used very largely nowadays for determining the necessary time for heat penetration, consists of a can, procurable in any desired size, fitted with a gasket which is easily screwed to the can by means of the wrench. A self-registering thermometer is attached so that the bulb is in the exact center of the can, for this is the point to which the heat must penetrate to insure complete sterilization. The mercury in the thermometer is shaken down, the can filled, sealed, and put through the process with the other cans. It is afterward opened, and the maximum temperature reached is read on the thermometer. Another form of instrument is a can fitted with a thermo-couple. Wires lead to a recording instrument outside the can, and the progress of the temperature is recorded on a chart. By experimenting with these cans, valuable data may be obtained for different temperatures, times, etc. The processes which were successfully used years ago are now unsafe, because as time goes on larger numbers and more resistent kinds of organisms have to be dealt with.

During this study of micro-organisms it was discovered that weather conditions affected the bacteria on the crops, that uncleanliness and delay in handling raw materials meant the multiplication or the introduction of undesirable organisms which were very hard to kill. Hence processes are varied slightly with weather conditions, and every packer guards against bacterial multiplication by the rapid and careful handling of all his products, otherwise excessive temperatures would be required, and of course the longer and more intense the heat, the less presentable is the finished product.

By this careful study of organisms and the changes brought about by these organisms in different classes of canned foods, two distinct divisions have been made in sterilizing. It was found that the spores of spore-bearing organisms are very difficult to kill; in boiling water they could survive for hours, but that 10 to 15 minutes at 240 deg. Fahr. usually killed them; it was also found that these spores would not develop in media having an acidity above 0.3 per cent. On the other hand, yeasts, molds, and some non-spore bacteria were able to grow in a moderately acid medium, but were easily killed in boiling water. Hence, when any foods of high acidity, such as fruits (and tomatoes), are canned, it is usually in boiling water for varying lengths of time, while the non-acid products (vegetables) receive temperatures above 212 deg. Fahr. in order to kill the spores. This then is the line of division between the use of the open bath (or boiling water) and the retort (or temperatures above that of boiling water).

When the packer became aware of the many possibilities of loss, he introduced a system of testing his products now known as the incubation test. A room is maintained at a constant temperature of 98 deg. Fahr., and from each cook a few cans are taken, carefully marked and placed in this room for about five days, when any unkilled organisms will have had time to develop. The cans are then examined physically and microscopically, and if anything abnormal is found, the corresponding batch, which will still be in good condition, is located in the warehouse and the goods are discarded or re-treated, depending on their condition and the cause of the trouble. Thus the packer is able to put his products on the market with a reasonable assurance that they will keep, but of course occasional cans may later develop a leak and the contents be spoilt. It is essential in this work to have the room maintained at 98 deg. Fahr., because most organisms with which we are concerned develop best at this temperature, while some develop only slowly at temperatures above or below this.



Filling cans of baked beans.

This mechanical slitter cuts fish into sections that will just fit into the cans.

By testing the finished products in this way, many irregularities have been noticed, and arriving at the cause of all cases of spoilage has led to many improvements in methods of sterilizing. Thus, it was sometimes found that the cans had been put in and never cooked, or else the time had been forgotten and the cook cut short. To overcome this, different forms of clocks which show the time, etc., on each cook are now used. Some of these are automatic and shut off the steam at the proper time. In other cases where only part of a batch was spolied, it was found that uneven temperature conditions existed, and hence the introduction of modern steam regulating and circulating devices.

One of the early difficulties encountered by the bacteriologist was the differentiation between a leak and a swell. To the layman this might seem simple, and of course in the case of a visible leak it is easy, but most of the leaks are so minute, and being on the seams or in the solder, they cannot be found. Organisms have entered these small holes, and the cans swell. The hole becomes cemented up with the contents of the can, and the foods or gases do not leak out. Sometimes a small hole will leak from the outside in, but not from the inside out; sometimes these holes are closed more firmly by the strain on the can. It became necessary then to make a bacteriological study to distinguish the cans spoiled by a leak and those spoiled by under-treatment, and we now have a very reliable distinction which was arrived at by a careful study of cans known to be under-treated, and those known to be leaking. I explained that in non-acid products it is necessary to not only kill the bacteria, but also the spores, which require a great heat in most cases. If therefore in a swelled can of food of low acidity we find only living spores or spore-bearing organisms, it is safe to say that the can has not been sufficiently sterilized; on the other hand, if we find lactic acid bateria present we know that the can leaks. This conclusion is very sound; the lactic acid bacteria are very prevalent in the air, they are very minute and can pass through a very small hole, and they are the first organisms to seize on any matter containing sugar; hence if any air is drawn into the can through a small leak these lactic acid organisms will be present. There may be others, too, but the presence of living lactic acid bacteria is proof of a leaky can.

In the case of the acid products, the differentiation is not so easy, and requires considerable experience and judgment. As I said, the spores do not develop in this class of foods, only the yeasts, molds, and some non-sporing bacteria, and in an under-treated can we find some one of these present in pure culture, while in a leaky can there are several varieties of each or all.

These conclusions are drawn of course only when the cans have been subjected to a fair degree of heat, which is ascertained by a physical examination of the contents

and the can. For instance, in tomatoes, when a fair amount of heat has been applied, the gelatinous envelope surrounding the seeds will be removed; in the case of fruits, the color, softness, etc., is an indication of the degree of cooking. In the case of foods given a heavy treatment, as is necessary for vegetables, the inside of the can will have a bluish cast and galvanized appearance.

Besides the bacterial examination of swelled cans, it is customary to empty the can, clean in hot lye, reseal, and subject it to a pressure test under hot water. Very frequently minute holes are found in this way, but the method is not so reliable as the bacterial examination, for some leaks become cemented so firmly that they can withstand high pressure.

An examination of the gases present also aids in this work. In all cans there is a certain amount of head space, and the gas in this head space would be expected to consist of the constituents of the air, plus any other gases formed in the sterilizing, but it has lately been shown that changes take place whereby practically all the oxygen in cans or fruits disappears, and only nitrogen, hydrogen, and carbon dioxide remain. This disappearance of oxygen is accounted for by the formation of oxides with the tin and iron; by the oxidation of iron and tin compounds; or by combination with hydrogen which is formed by the action of the acid on the tin plate. The hydrogen does not appear in this head space until all the oxygen is consumed. In the case of vegetables we may have sulphureted hydrogen and phosporeted hydrogen formed by the breaking up of the protein matter under the high heat, along with nitrogen and possibly some carbon dioxide and oxygen.

Now let us look at spoiled cans. In the case of a leak a large proportion of free oxygen would be found; in the case of a swell in fruits we would find the regular gases of alcoholic fermentation (carbon dioxide and hydrogen); in the case of swells in vegetables due to under-treatment we find large amounts of foul gases such as sulphureted hydrogen, phosphoreted hydrogen, etc. You can see therefore that the examination of the gases in conjunction with the bacteriological examination is a valuable aid in determining the cause of spoilage.

An instrument for drawing off the gases from a swelled can consists of a hollow needle for puncturing the can. A rubber stopper makes a tight joint to prevent gases escaping at the hole. A screw presses the plate up and forces the needle through the can, the gas being led off through the needle to a collecting apparatus. A later type of instrument has an auxiliary tube to force water into the can, and thus drive all the gases out for quantitative work.

In the canning industry we use certain terms in describing spoiled cans, namely, leaks, hard swells, flat sours, and springers. A *leak* is one where the food is spoiled by the entrance of organisms through a small hole. Some times these holes are visible, especially if due to the faulty capping of the can, but more often the leak is invisible. By a *hard swell* is meant a can which is swelled out perfectly tight by the gases evolved in the spoilage, and no amount of pressure will force the can back to normal size and shape. This class represents an advanced stage of spoilage, and when the pressure generated inside becomes sufficient, the can bursts at the weakest part, usually on the seam. A hard swell in vegetables is usually foul smelling, due to the malodorous gases formed in the breaking down of the vegetable matter by the spore-bearing organisms; a hard swell in fruit does not give foul gases, but only the ordinary gases of alcoholic fermentation. Generally speaking, hard swells are the direct result of under treatment.

By *flat sours* are meant cans which, to outward appearances, are perfectly normal, but when opened contain foods which are very sour or bitter. This occurs in corn, peas, beans, pumpkin, tomatoes, etc. They may have gone sour previous to being packed, but this condition is rare. The principal cause is under-treatment; the bacteria bringing about this result are spore bearing; they generate practically no gas; are anaerobic, and hence live on the carbohydrates, producing lactic acid. They are rather slow to develop, and therefore spoilage may not show for months, but if the incubator test is used, the spoilage will develop in about 10 days at 98 deg. Fahr. From the fact that the cans are outwardly of good appearance, this class of spoilage presents great difficulties to the packer. When parts of a pack get into this condition, it is a matter of careful and painstaking work to separate the good from the bad, and even when all care is exercised, the methods used are not entirely satisfactory. One method is to put the cans into boiling water, bottoms up. The expansion of the contents of the cans causes the ends to snap out, and of course the sour cans snap out first. By frequent cutting of the cans during the heating, a time is arrived at between the snapping out of the sour cans and of the good ones. Another method is to heat the cans until they all snap out, then cool them, and separate the good cans which snap back first. The success of either method depends largely on the operator, and is only approximately correct, because variations in filling, exhausting, etc., of the cans affect, the separation.

Springers are those cans where the vacuum is broken, the ends have sprung out, but may easily be pushed back again. This condition sometimes exists in vegetables, but in this class of foods a springer will likely develop into a hard swell. The most frequent trouble with springers is in fruits and tomatoes, so the term applies particularly to these. There are two subdivisions in springers; those in which are living organisms, and those in which no living organisms are found. If living organisms are found, the trouble may be due to a leak or under-treatment, and if the latter, a hard swell would probably develop later on. Some springers, however, have no living organisms. The action of the acids on the tin plate evolves hydrogen, and if there is very little space in the can, the gas when expanded by heat causes the ends to flip out, hence cans should not be filled too full; sufficient head space must be left to allow for the expansion of the gases present. Another cause may be insufficient exhaust, i. e., the heating of the foods before or after they are in the can, and previous to capping. This is done to expand the contents and drive out the excess air. The cans are then sealed at once, heated, and after cooling there is a contraction, and the ends of the can are drawn back into place. If the exhaust is insufficient, the ends will not draw back properly. Another cause of springers is when fruit seeds or stones are present and their seed life has not been killed, a development of the embryo will have taken place, with production of carbon dioxide in sufficient amount to cause the ends to flip out.

Discolorization in canned foods.—Much trouble is encountered due to loss of color or development of undesirable colors in fruits and vegetables, and many of these troubles have been accounted for. The color of such fruits as strawberries, raspberries, and cherries is very delicate and easily destroyed. It was found that some of this was due to the action of the acid on the tin plate, iron compounds, which darkens the fruits, being formed. In other cases the fruits lose their color altogether, and as far as I know, there is no explanation of this, except that the chemical compound constituting the color is destroyed by the heat. Light colored fruits, such as peaches, pears, and apples, sometimes turn pinkish or brownish. As this may develop in enamel cans, plain cans, or glass jars, the cause must be chemical; the brown color is due to caramelization of the sugar by over-cooking, but what the pink color is due to is unknown; it is probably an early stage of this caramelization.

Another frequent cause of trouble in white fruits is the presence of black spots. In preparing fruits it is necessary to immerse them immediately in water or dilute salt solutions to prevent them from turning dark by exposure to the air. Sometimes a very dilute sulphite solution is used to retain the color, this afterward being washed off. However sometimes a little sulphite remains on the fruit; then if there should be any appreciable amount of iron in solution, either from the tin plate, the knives used in peeling, or from the water, black iron sulphide is formed under the effect of heat, and hence the black specks.

In the case of vegetables the greatest difficulty is experienced with dark corn, and there are several reasons for this. This article is subjected to very high temperatures, as much as 250 deg. Fahr. for 60 minutes. If the corn is not cooled rapidly there will be a marked discoloration due to caramelization of the sugar. The most frequent trouble, however, is from black iron sulphide formed by the combination of iron and sulphur. Discoloration of this kind is most frequent on the cap end or along the seams; the iron is usually derived from the tin plate by the action of the acids liberated from the flux by heat. The iron might also originally be present in the flux, or in the water. The sulphur is present as sulphureted hydrogen, formed by the breaking up of proteid substances.

In the green vegetables such as peas, beans, etc., we have loss of color due to the destruction of chlorophyll by the heat. To overcome this, the French usually treat the peas with copper sulphate, but this method is not used extensively in Canada or the United States. Other methods have been proposed for preserving the color, and these aim to fix the chlorophyll as an insoluble compound on the vegetables. Such methods employ solutions of salts of calcium, barium, or strontium, but their value has not yet been proven.

The question of how to retain the natural color of fruits and vegetables presents a good field for research, especially in the case of vegetables.

Canning of peas.—Last year's pack of peas ranked third in importance in the United States; the quantity packed amounted to a little over 7 million cases, or 168 million cans (the largest pack was tomatoes, 14 million cases; then corn, 13 million cases). Modern harvesting is done entirely by machinery, the vines being cut about the same way as hay. Special machines, called viners, handle the cut vines, removing the peas from the pods by beaters. The peas fall through perforations in a cylinder, large enough to allow the peas to pass through, but which retain the vines, pods, etc. Sometimes these viners are placed in the fields, but more often the farmer hauls the vines to the viners at the factory. The peas from the viners are next washed in cold water, in a revolving squirrel cage, to remove all the dirt and some of the mucous substance which adheres to the peas. The next step is the grading, which is also done in an inclined, revolving squirrel cage. These cages are perforated in sections, with different-sized holes, the first 9/32 inch diameter, through which pass the '*petit pois*'; the second size, 10/32 inch, giving the extra sifted peas; the third size, 11/32 inch, the No. 3 or sifted pea; the fourth size, 12/32 inch, the early June peas; those that pass out at the end are marrowfats or standards. Some packers however, only produce three grades, and arrange the sections of the grader accordingly. There is also a method of grading peas for quality according to their density by using different strengths of salt solutions. The first grade floats in a solution of specific gravity 1.040, the second grade sinks in this solution, but floats in a solution of specific gravity 1.070, while the third grade sinks in the latter. This grading for quality coincides very well with the grading for size. After the peas are sorted or graded, they pass over a wide belt, on each side of which are seated women who pick out the foreign material and the broken and defective peas. The next operation is the blanching, the object of which is to remove the mucous substance from the peas, and to drive water into the peas so that they will be soft and tender. This is done in boiling water for from 1 to 12 minutes, depending on the peas. It is one of the most important steps in the handling of peas, and requires experience and good judgment. The machines for blanching are of the squirrel-cage type, revolving in water, and the speed can be varied to deliver the peas at the outlet in the proper time required. The water flows in the opposite direction to the motion of the peas, so that as the peas come out they receive clean water. The peas after blanching are washed with cold water, and then go to the filling machines, where they are automatically filled into the cans, the brine of salt and sugar being added at the same time. The cans are then capped by machinery, heated in retorts at 230 to 240 deg. Fahr. from 25 to 40 minutes, depending on the quality of the peas, then the cans are cooled and stored away. Delay may mean production of sour peas, or multiplication of bacteria, which would not be killed in the process, and would produce swells.

A most desirable quality in canned peas is to have them open up with a clear liquor. Very frequently the liquor is milky or cloudy.

Examination of this cloudy liquor shows it to have a high content of starchy material; that is, the starch has passed from the peas to the brine. This may come about by over-cooking, which would break the peas; by not properly cooking the peas after heating, which would allow a slow cook to go on; by improper grading, when the smaller peas would be overcooked; by mashing at the filling machines, overfilling the can, when the expansion would mash the peas. If the peas are not properly blanched to remove the mucilaginous matter, this will cloud the liquor. If there has been any heating (sweating) of the peas previous to canning, the liquor may be cloudy, because of the slime produced by the bacteria, and this slime is very difficult to remove by washing or blanching. A most frequent cause is the canning of overmature peas, when the starch-content is higher than in young peas. All of these points, however, are dependent more or less on the skill and care of the processor.

Even with careful watching of all these points we may have cloudy liquor, but the causes are more of a chemical nature. For instance, if the water that is used is very hard, the lime and magnesia combine with the albumins, forming insoluble albuminates, which give the peas a thin hard shell which will not expand in the heating, but cracks and allows the starch to pass through into the liquor; the water itself might also become cloudy due to precipitation of the temporary hardness. It becomes necessary therefore to have a good supply of soft water, and in many places the water is purified to overcome these possibilities.

Some seasons, and in some districts, the peas are high in starch, and it is almost impossible to obtain clear liquor. A means for converting the starch into a soluble compound by means of an alkali such as sodium carbonate suggests itself. There is also the question of the solubility of protein matter in water, salt, and sugar solutions: the protein of the pea is more soluble in salt solution than in water. Experiments in Germany indicate that the use of excess of nitrates as fertilizers produces peas which tend to give cloudy liquor.

Tin plate.—The canning industry calls for the use of large quantities of tin plate for can making. This plate must be of good quality, free from pin holes. The estimation of tin in tin plate presented many difficulties, but we now have reliable methods. A neat method for the detection of pin holes and imperfections in plate consists in coating the plate with a solution of gelatin, potassium ferricyanide, and sulphuric acid. At the end of thirty minutes the pin holes or scratches are located by the blue spots due to the interaction of the iron and potassium ferricyanide.

Some food 'aws not only specify the amount of tin on the plate per base box, but also limit the amount of tin which should be present in the foods. This, of course, entails frequent examinations for tin, which in the presence of so much organic matter is very difficult. This question of solution of tin by the contents of the can is very important. Many people believe that old canned foods are undersirable because they contain too much tin; but recent investigations show that such a procedure is unnecessary and of no value; if the contents remain in an opened can, very large amounts of tin go into solution, and for this reason cans should be emptied immediately after opening. The cause of this excessive solution of tin is the oxygen of the air. As already shown, in sealed cans the oxygen disappears in a short while, and along with this disappearance of oxygen the solution of tin practically stops. The maximum amount of tin goes into solution in about three months, and after that there is very little change. The U. S. Department of Agriculture investigating in California the question of effect of age on canned foods, and their results show that canned foods which have been packed for some time are actually better than those only packed a short time, and therefore the dating of canned foods would not be of any great benefit.

Solder.—The solder must be clean and free from dross, for the presence of the latter means pin-hole leaks. It must also be free from excessive arsenic and antimony, which would affect the flow, and if introduced into the food would be harmful. At present there are two principal grades of solder used: 40 parts tin, 60 parts lead; and 45 parts tin, 55 parts lead. Until recently solder was supplied in the form of wire or cable, which was fed to the irons automatically. In the recently introduced solder-hemmed caps, the solder is in the form of a ribbon on the edge of the caps. This presents a great saving in solder and labor.

Flux.—The requirements of a flux are that it must be free from iron, and it must not be acid; also sal-ammoniac in any quantity is not desirable. At present a neutral zinc chloride solution free from iron is found best; resin, dextrin, oils, and other organic substances are also used, but they are not very good as they gum up the cans.

Water.—A very important item in the canning factory is the water. Nearly all the factories are in small towns or villages where the only supply is from wells. The water should be free from pathogenic organisms, because although any pathogenic organisms are killed in the sterilization, still some non-pathogenic organisms which would be hard to kill might be introduced. The water should be free from iron; aeration of the water, with filtering or settling, is usually sufficient to eliminate it. Water high in lime and magnesia forms insoluble compounds with albumins, thus tending to harden vegetables, and where these waters are encountered a purifying system should be installed.

As regards the question of scale in the boilers, latest figures show that a one sixteenth scale increases the coal consumption by 12 per cent; so in the case of excessive scale-forming waters, boiler compounds are used. However, as so much live steam is used, coming in direct contact with the food, most boiler compounds are objectionable, and hence purification outside the boiler is resorted to.

Salt.—Large quantities of salt are used for brines in vegetables, etc., and this salt must also be free from iron and much calcium and magnesium salts. Magnesia may also cause undesirable bitterness of the brine.

Paste.—In the past, considerable trouble has been encountered with rusty cans, due to the paste used in attaching the labels. There are now good pastes which do not rust the cans nor soil the labels.

Sugars.—Only pure granulated sugar is used in canning, and fortunately this is always offered in high grade. For syrups I do not think there is any appreciable difference between cane and beet sugar. If beet sugar is properly refined (freed from raffinose) there is no chemical difference between it and cane sugar. The only difference is in the grain and color, but these are hardly sufficient to cause any trouble. Beet sugar usually forms more foam than cane, but this, I think, is due to the fineness of grain rather than to anything else.

Miscellaneous.—There are numerous miscellaneous products used such as coal, vinegar, spices, disinfectants, washing powders, etc., all of which are tested in the laboratory.

Gages and thermometers must be regularly tested. The steam gages must be correct to avoid explosions, and the thermometers must be correct to avoid losses in cooking.

Sewage disposal.—In the past every effort has been made to eliminate any nuisance from this source, the solid particles being removed by screening, and returned to the land for their fertilizing value, the screened effluent being run into a large body of water. This effluent consists of the washings from fruits and vegetables, and contains large amounts of nitrogenous matter; in dry seasons there may possibly be some putrefaction which is not harmful to health but may produce objectionable odors. Now that the Provincial Board of Health regulations prohibits all sewage or factory effluents from being poured into streams without purification, it will be necessary as time goes on and occasion demands it to put in purification systems, possibly on the lines of the septic tank and filter beds.

Utilization of waste products is not overlooked in the canning industry. The small fruits, trimmings, etc., are sometimes extracted for their juice for fountain syrups.

The apple wastes such as peelings and cores are either dried and sold for wine and vinegar purposes, or else the juice is pressed out and sold as cider, or made into cider vinegar. Unfortunately the demand for cider vinegar in Canada is not sufficient to allow of the profitable treatment of apple waste for this purpose. However, it is very profitably turned into apple jelly to be used as the base for compound jams. When these wastes are properly handled, no objection whatever can be taken to their use.

In pea canning large quantities of pea vines are left over, which make very good ensilage. Some factories have their own silos, and sell the ensilage in the winter, while others allow the farmers to take the vines away free of charge; in other places it is necessary to pay to have them carted away.

In corn canning there are large quantities of corn silk, a small part of which is used to make extract of corn silk for medicinal purposes. The use is limited, however, but we hope some day to find a large and profitable outlet for corn silk. The corn stalks, corn cobs, and husks, make good ensilage. The question of production of alcohol has been investigated, but it was found that the recovery of alcohol would hardly pay for the cost of installing a plant.

Large quantities of seeds from tomatoes and pumpkins, as well as the stones, etc., from cherries, plums, and peaches, are now being utilized for their oil.

Many companies now have experimental farms, including several in Canada carried on by the Dominion Canners, the largest of which, situated near Brantford, is about 1,000 acres, and is devoted entirely to seed production.

In the modern factory equipment the effect of the laboratory can be seen. The old retorts are being supplemented by ones in which the cans are agitated, thus shaking the contents and lessening the time of penetration of the heat, cutting down the time of sterilization, and giving improved flavor and appearance.

No doubt the future will see the more general adoption of the intermittent system of sterilization, that is, instead of sterilizing in one operation at a high heat to kill the spores, the sterilizing will be accomplished in two operations at lower temperatures; the first will kill all organisms except the spores, then in two or three days these spores will have developed, and a second heating will kill these developed organisms. This of course entails handling the product twice, and hence would be costly, but no doubt can be worked on a small scale, and the increased quality and appearance of the goods will bring a higher price.

In place of the old iron pipes and iron parts on cookers, filling machines, etc., there are now copper, brass, enamel, or silver. In place of the old wooden floors is concrete, and in place of the old wooden top tables, enamel or even glass tops; in fact, everything is arranged so that a hose can be turned on and the factory washed out very rapidly.

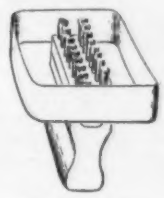
In Germany the canners subscribe to a large laboratory and experimental factory; in the United States there are many private laboratories, and now a laboratory under the Canners' Association is to be started. In Canada, the Dominion Canners are the largest corporation, and they have their own laboratory and experimental departments.

The canning industry makes it a practice to investigate all the reports as to alleged ptomaine poisoning due to canned foods, and in practically every case gets a denial of the charge. A ptomaine is described by Vaughan and Novy as "an organic chemical compound, basic in character, and formed by the action of bacteria on nitrogenous matter," or in other words it is a putrefactive alkaloid, a product of decomposition. There are many known ptomaines, but very few of them are really poisonous. The poisonous ptomaines may be formed by pathogenic organisms, by a few yeasts and molds, and a few anærobic spore-bearing organisms, all putrefactive in their action. There must be putrefaction to get poisonous ptomaines, and no packer would think of packing putrefactive products, so the only possibility arises where a can has leaked or swelled. Of the hundreds of reported cases of poisoning from canned foods, I only know of one where the charge was proved, and that was from a can of salmon that had a pin-hole leak, and the consumer should not have eaten the contents, which were abnormal. Physicians and others should be very careful before diagnosing a sickness as due to ptomaine poisoning caused by eating canned foods; an injury is being done to a large industry, and the public are needlessly scared.

Canned foods are generally regarded as non-perishable products, and are consequently put into a shed or damp cellar which is not fit for anything else. The result is that the labels are discolored, the cans rust, and pin-hole leaks result. Although freezing does not materially alter the flavor of canned foods, it is not advisable to allow them to be frozen, for when they thaw out the cans sweat and rust very easily. All canned foods should be stored in a dry place, of even temperature, with good air circulation around and underneath the pile.

A Fish Scaler

When the scales of a fish are removed by scraping with a knife, they are apt to be scattered over the floor and to fall into corners and crevices and remain there, because they are overlooked or inaccessible, until their presence is revealed by disagreeable odors.



Fish Scaler.

The knife may advantageously be replaced by the brush herewith illustrated, which is surrounded by a sheet metal guard in the form of a box, which prevents the scattering of the scales. This novel fish scaler appears to be a very practical and useful kitchen accessory.

Correspondence

[The editors are not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.]

Curiosities in Numbers

To the Editor of the SCIENTIFIC AMERICAN SUPPLEMENT:

The following relations which I have observed to exist between certain series of numbers may interest some of your readers.

(*a*) $1^3+2^3+3^3+ \ . \ . \ . \ +n^3=(1+2+3+ \ . \ . \ . \ +n)^2$

(*b*) $1^2+2^2+3^2+ \ . \ . \ . \ +n^2=(1+1)+2(1+2)$
$+2(1+2+3)$
$+$ etc.
$+(1+2+3+ \ . \ . \ +n).$

New York. JOHN LOTKA.

[Our mathematical readers may find it an interesting problem to prove the relations given above. We shall be pleased to receive communications on the subject, and to publish in a later issue such solutions as commend themselves for their mathematical neatness.—ED.]

Mathematical Diversions

To the Editor of the SCIENTIFIC AMERICAN SUPPLEMENT:

Your "Mathematical Diversions," per Mr. Selkin, in issue of June 21st SUPPLEMENT pleased me very much. Many years ago a Presbyterian pastor in Seneca County, N. Y., offered $5 to a young lady if she would arrange the 9 digits and the cipher so that their addition would result in the sum "100." She failed to secure the prize and I tried in my boyhood for a long time so to arrange the stubborn figures, but failed. But I did not forget the matter and nearly 30 years ago while living and teaching in New Jersey and reviewing the subject of arithmetic with the senior class of the New Brunswick High School, I brought it up before the class as an item of interest. (I might truly say of *additional* interest) and in explaining how it should be done I went to the blackboard, took a piece of chalk and said "*write the figures down something like this, using all the ten characters but using none more than once.*" So saying I put down at random the

following:
19 8/4
20
57 6/3

and to my intense surprise these very figures when so arranged and added produced the long coveted "100." It was one of the most remarkable coincidences I have ever experienced. Since that time, however, I have found a large number of solutions and I verily believe they are to be made by the score. At least I had nearly one hundred in an old scrap-book upon which, unfortunately, just now I cannot place my hand.

Westfield, Mass. CHARLES JACOBUS.

P. S.—I append two illustrations which I just made in a minute or two:

$$78+\frac{45}{3}+\frac{60+2+1}{9}=100$$

and

$$\frac{90}{45}+67+28+\frac{3}{1}=100$$

Fig. 1.—Top view.

An Automatic Astronomical Calculator

Long and Tedious Computations by Nautical Tables Rendered Unnecessary

By Arthur H. Brown

Fig. 2.—Side view.

Readers of the Scientific American Supplement this week have the privilege of examining the first published description of an invention which is remarkable for being fundamentally new, both in regard to the results secured by its use and to the mechanism involved, as it is the only thing of its kind, and is capable of securing, automatically and immediately, results which have hitherto been obtained only through long and difficult mental labor. This invention, conceived by Mr. Horace S. Butterfield, of Portland, Ore., has been embodied, with the assistance of Mr. Olof Ohlson, in a scientific instrument which is called "The Butterfield Azimuth Chronometer," and is shown in the three engravings on this page.

The value of the instrument will be at once apparent to navigators particularly, and also to surveyors, and others who have occasion to determine terrestrial positions and directions from astronomical observations, when it is realized that by its use the following determinations may be made instantly and automatically, *without calculation or reference to tables;* and with great accuracy.

(1) The position of a ship at sea may be found, or the latitude and longitude of any spot on the surface of the earth determined.

(2) The true directions may be determined independently of the compass, and compass errors detected and corrected.

(3) Local time may be accurately determined.

(4) These determinations may be made at any hour of the day or night when the sun or a known star is visible, even though the period of visibility is very short.

Anyone who has even the most elementary knowledge of navigation, or who has ever tried to work out the position of a ship from the usual observations, or who has known the anxiety caused by the uncertainties of the magnetic compass, will understand the inestimable benefit which such an instrument, which saves the time and mental labor, and above all, eliminates the liability of error, involved in these determinations, must be.

The need for an instrument of some sort for simplifying the processes of applying astronomical observations correctly to the uses of navigation became apparent to Mr. Butterfield through information obtained on shipboard, when he became deeply impressed by the facts, well known to all navigators, that an immense amount of time and labor is required to take observations of the sun and stars and work out the position of the ship from these observations, and that errors are liable to occur at all stages of the calculations; that long periods of time frequently elapse in cloudy weather when observations at noon and at the other usual fixed times cannot be taken, and that brief intervals of clearing at other times, when the sun is visible for a few moments, cannot be conveniently made use of for taking observations; and above all, that magnetic compasses are far from reliable, and that the adjustment of their errors is a tedious proceeding and one of constantly recurring necessity.

The same need has also been given official recognition by the United States Navy Department. In a circular letter of February 26th, 1912, from the Acting Secretary to all the officers of the Navy, attention was called to the fact that the science of nautical astronomy had not advanced as rapidly as other sciences in recent years, and that the Department was desirous of developing new nautical instruments and new ways of using instruments and principles already available so as to increase the accuracy and ease of determining positions at sea from observations of heavenly bodies; and the officers were urged and encouraged to bring all available new ideas and information relating to new instruments and methods to the attention of the Department.

The methods heretofore necessary, and now generally practised, for determining compass errors and adjusting compasses, and for determining the position of the observer on the earth's surface, by astronomical observations, involve a cumbersome series of observations by the aid of different instruments, and complicated calculations, including the solution of a spherical triangle, with reference to numerous tables of constant and variable values. Even certain recently devised methods of simplified navigation, by which more or less close approximations of the true position at sea are obtained, involve a considerable amount of calculation and reference to tables. The use of the Butterfield instrument greatly simplifies the observations to be taken for these purposes, and wholly eliminates all calculations, securing results fully as accurate as can be obtained by the most careful observations with the best instruments, correctly worked up, and much more accurate than are usually obtained by navigators.

The salient features of the instrument are, sighting vanes 1, 2, mounted to rotate horizontally on ball bearings in the center of a pelorus plate 3 (which is itself adjustable about the same axis), a timepiece furnished with the usual hands, and a transmission mechanism through which

Fig. 3.—The instrument turned so as to expose the working parts.

motion is imparted from the timepiece to the sighting vanes at a variable rate, corresponding at each instant to the momentary rate of change in the bearing of the sun or other heavenly body. The timepiece and transmission mechanism are hung beneath the pelorus and may be inspected and set, by inverting the pelorus in its support, into the position shown in Fig. 3, to which the reader is referred for illustration of the description following. The timepiece 4 drives an annular gear 5 by a pinion, not shown, which is connected with one of the arbors of the timepiece. This annular gear is the segment of a spherical shell and rotates about the timepiece. It also carries pivots 6 to which there is swiveled a band 7 surrounding the gear and carrying studs 8, of which there are two (only one being shown). These studs are rotated with the gear 5 and drive a yoke 9 which is provided with a guideway 10 formed to receive the studs. The yoke 9 is semicircular and is connected at its middle portion with a stud 11 (Fig. 1) to which is also connected the arms 12 carrying the sighting vanes. It is arranged in the same plane with the central lines of the arms 12 and sighting vanes.

The timepiece is carried by a frame 13 springing from a slide 14 which rests and slides on the inner surface of a semi-circularly curved bar 15, hanging from the under side of the pelorus plate and being rigidly connected to the plate. Regulated adjustments of the slide 14 along the bar 15 are made by turning a head 17, which is carried by the slide, and is connected with a pinion 16 in mesh with a line of teeth on the bar 15. The bar is graduated on either or both sides in angular degrees running both ways from the zero mark, and on the slide 14 there are index marks and vernier graduations. The bar 15, gear 5, band 7, and yoke 9 are all concentric with a single central point (or common center of the parts above described) which lies in the axis of rotation of the sighting vanes, and all the movements of adjustment and running of the moving parts take place either about this point, or about axes passing through this point. The axial line of the pivots 6 and the line between the studs 8 also pass through the same common center.

By adjustments of the slide 14 along the bar 15, the timepiece and annular gear 5 may be swung angularly about this common center on a horizontal axis, thus setting the gear to rotate in planes making various angles with the axis about which the sighting vanes rotate, that is with the perpendicular when the instrument is in position for use. This adjustment is for the latitude of the place of observation, and is made with reference to the scale on the bar to place the axis of the annular gear parallel to the earth's axis and its plane parallel to the plane of the earth's equator, when the plane of the curved bar 15 has been set by proper rotation of the pelorus plate, in the true meridian. The scale of angular degrees on the side of the bar 15 thus represents degrees of terrestrial latitude. The paths of rotation of the studs 8 are also adjusted in the same way by the same adjustment, subject to a secondary modified adjustment by a declination gear, by which the angle of the band 7 about its pivot 6 with respect

to the plane of the gear 5 is made to correspond with the declination of the sun at the time of use of the instrument.

This declination gear, invented and developed by Mr. Olof Ohlson, comprises a spherical cam, one edge of which is shown at 18 (Fig. 3), rotatable about the axis of the gear 5 and having a cam groove for acting on the band 7. The angular distances of the points in this cam groove from the axis of the gear 5, measured about the common center above mentioned, correspond to the declinations of the sun on all the different days of the year. Thus when the gear 5 is set for the latitude of the place of observation and the declination gear is set for the declination of the sun on the day of observation, one of the studs 8 rotates in a path having the same relation to the equatorial plane of the driving mechanism that the parallel of latitude which is directly under the sun on that day has to the earth's equator. The other stud is placed in a corresponding position at the opposite side of this plane. By "equatorial plane of the mechanism," is meant the plane, perpendicular to the axis of the gear 5, which passes through the common center. The gear 5 makes one complete rotation in twenty-four hours and operates a pawl and ratchet mechanism once in each daily rotation to turn the declination cam through one three hundred and sixty fifth part of a revolution, with the result that, if the timepiece is kept running at an accurate rate, the declination cam will be automatically moved day by day until it has made an entire rotation in the course of a year, and in its daily movement will shift the studs correspondingly to the daily changes in the sun's declination.

On the cam are date graduations, showing the days and months of the year, placed beside the points of the cam groove which have eccentricities corresponding to the sun's declination on those days, and on the band 7 is an index (not shown in the cut) beside the line of graduations. As the ratchet and pawl mechanism is so made as to permit a manual adjustment of the cam, the latter may be set, with reference to the graduations and index, and regardless of whether the timepiece has been kept running or not, so as to adjust the studs for the declination of the sun on the day of use, or for any star of which the declination is then not greater than about twenty-three and one half degrees. The timepiece is also equipped with a setting device by which the hands and transmission mechanism may be set to any time indication, and there is a positive connection between the hands and the pinion which drives the gear 5, which is independent of the connection of the hands with the movement of the timepiece, so that any adjustment which changes the position of the hands correspondingly changes the position of the sighting vanes, and *vice versa*.

The mode of operation and the principles on which the instrument operates may best be understood by considering first the operations in the extreme settings for latitude. Consider first the setting for latitude ninety degrees north, the position of the north pole. When the slide 14 is shifted to the right (with respect to Fig. 3) until its index mark is brought beside the ninety degree mark on the bar 15, the axis of the gear 5 is brought into coincidence with the axis of the sighting vanes, the graduations on the bar being so placed as to secure this result. Then, as one or both of the studs 8 are in the guideway of the yoke 9, and as the studs rotate at a uniform rate about the common axis of the gear 5 and of the yoke, the latter and the sighting vanes are rotated at a uniform speed which corresponds to the motion of the sun as it would appear at the pole, it being understood, of course, that the direction of rotation of the mechanism (when in the upright position) is the same as that of the sun. The motion given the sighting vanes in this latitude adjustment is independent of any adjustment of the stud for declination, because the studs and yoke rotate about the same axis, and the declination adjustment merely changes the position of the stud in the yoke, without changing its axis. Now let us assume that the adjustment is made for latitude zero, corresponding to a position on the equator, and that the declination gear is set for either equinox, when the sun is directly over the equator. Then the axis of rotation of the studs is perpendicular to the axis about which the yoke 9 and sighting vanes turn, and the path of the studs is in the equatorial plane of the driving mechanism. Shifting of the mechanism into this adjustment has brought the yoke 9 into the plane in which the studs travel, because one or the other of the studs is always in the guideway of the yoke, since the studs are on opposite sides of the common center and the yoke extends through an arc of one hundred and eighty degrees, or slightly more, around the same center. As the yoke now coincides with the path of the studs, the latter merely travel through the guideway in the yoke without imparting any movement to the yoke or to the sighting vanes, thus meeting the condition on the equator at the equinoxes, when the sun does not change its bearing except as it passes from east to west in crossing the meridian. In any intermediate adjustment for latitudes between the equator and the pole, the studs travel in a plane inclined to the axis of the yoke and of the sighting vanes. Each stud in turn enters the yoke, and propels it, at the same time traveling up and then down in the guideway. In this way the yoke is given a variable motion which is slowest when either stud is entering or leaving the yoke, and most rapid when the stud is passing its position of greatest elevation and is nearest to the axis of the yoke. At this time the plane of the yoke coincides with a plane including the stud and the axis about which the stud rotates, and the point of the yoke on which the stud bears moves at the same speed as the stud. At all other times the yoke is more or less oblique to the path of the stud. When one stud passes out of one end of the yoke, the other stud simultaneously enters the opposite end of the yoke and carries the yoke through the remainder of its rotation. Thus in each twenty-four hours the yoke and sighting vanes are given a complete rotation at a variable speed containing two accelerations and two retardations. The rate of acceleration and retardation varies according to the obliquity of the axis of the studs to the axis of the yoke, and to the positions of the studs for declination.

The movement so given the sighting vanes corresponds to the horizontal component of the orbital movement of the studs, and so to the change in bearing of the sun, because the yoke always keeps the vanes in the same vertical plane with the studs, and because the studs travel in orbits corresponding to the path of the sun. Thus, when the latitude and declination adjustments are correctly made for the place and day of observation, and the pelorus is placed with its north and south line in the meridian, the sighting vanes show the true bearing or azimuth of the sun at each instant, as long as the timepiece is kept running. It is this relation between the latitude, time, and direction adjustments of the instrument which enables it to accomplish the purposes for which it is designed. The vertical component of motion of the studs is taken care of by the sliding of the studs in the guideway in the yoke.

When mounted for use the pelorus plate is hung in gimbal rings on any sort of pelorus support. The plate with the attached driving mechanism is rotatable upon the inner ring. The rotating arms carrying the sighting vanes are provided with an adjustable counterpoise 19 and a spirit level 20 for securing exact horizontality. The sighting vanes are equipped with the usual eyepiece 21, wire 22, and mirror 23 for taking sights.

The use of the instrument is a matter of the utmost simplicity. To determine the true directions for checking up the compass, the timepiece is set for the local apparent time and the latitude and declination adjustments are made according to the place and day of observation. Then by turning the pelorus about its center, which can be done easily and accurately by a thumb nut 24, until the wire 22 crosses the center of the sun's image in the mirror as seen through the eyepiece, the pelorus is so placed that its direction indications show the true directions. This observation may be taken at any time when the sun is visible, without reference to azimuth tables, and thus furnishes a direct means for determining the ship's course, as well as the variation, deviation, heeling error, etc, of the magnetic compass.

The position at sea may be as easily determined when the true directions are known. After the pelorus is set for direction, the latitude and time adjustments are manipulated until the sighting vanes are brought to bear on the sun. Then, if the latitude adjustment is correct, the vanes will follow the sun exactly, and readings can be taken from the latitude scale and from the face of the timepiece, which will show the latitude directly, and the longitude indirectly by indicating the local apparent time, from which longitude can be found by the simplest of calculations. If, however, the sighting vanes do not exactly follow the sun, this shows that the latitude setting is not correct and indicates the direction in which readjustment should be made, and further trial settings may be made until finally the correct readings are found. This determination of position when neither factor is known, may be facilitated by first finding the elevation of the sun with the aid of the sextant, and then so setting the latitude adjustment of the Azimuth Chronometer, that when the vanes bear on the sun, the stud is beside the angle graduation on the side of the yoke (see Fig. 3) corresponding to the sun elevation so found. When either the latitude or the longitude is already known, the other co-ordinates of position may be found without preliminary trial settings. These results may be secured by observations taken at any time of day when the sun is visible, not necessarily at noon, and the results are shown instantly and without calculations. The instrument is so designed that it may be used for all the purposes indicated in all latitudes of both hemispheres.

The Butterfield instrument is also well adapted for use in connection with the Gyro-Compass, firstly for quick orientation of the compass at its starting, and secondly for determining longitude when the compass is in reliable operation. As the compass can be depended on for always showing the true meridian, longitude is determined by setting the pelorus plate to coincide with the compass, and directing the sight vanes toward the sun by manipulation of the timepiece, when the timepiece will indicate local apparent time, which may be readily turned into longitude. It may also be used in the same way as an ordinary pelorus or azimuth instrument for taking observations on chartered objects. The same reasons which make the instrument useful to the navigator, make it equally useful to the surveyor and the engineer in establishing the meridian line and running a course.

All that has been said above with regard to taking sights on the sun applies to observations on the stars, to obtain the same results at night, provided the star selected for observation has a declination not greater than the maximum declination of the sun, and the timepiece is regulated for sidereal time. All declinations within that of the sun are taken care of by adjustments of the declination gear.

The instrument is adapted to be used also as a precision sun dial, but for this purpose the clock movement is not necessary. The hand-setting mechanism is retained, and is used to bring the sighting vanes into bearing with the sun, thus automatically setting the clock hands to show local time. A cam designed to correct for the equation of time will be used with the precision sun dial to cause the clock hands to show local mean time at any instant.

The Azimuth Chronometer above described has recently been installed upon the battleship "Rhode Island" of the United States Navy for actual sea trial and demonstration, the results of which have not yet been made public.

Shop Prints Direct from Pencil Drawings

In order to obtain blue-prints from a drawing it is first necessary to make an ink-line tracing of the drawing. This involves the cost of the tracing cloth, the cost of the time required in which to make the tracing and to check it with the drawing, and annoyance due to the delay in commencing work which has been ordered for quick delivery. By the use of an apparatus called the photostat, copies may be made direct from pencil drawings, cutting out the expense and delay referred to. This apparatus is practically a large camera equipped with developing and fixing devices and graduated scales for focusing without the use of a ground glass screen or dark slides, and without requiring a dark room. The drawing to be copied is photographed directly on to sensitized paper, which is in the form of a continuous roll, and means are provided for cutting off each sheet after exposure and for passing it into the developing bath without being touched by the hand. The image is a direct one, not reversed as in the case of a negative. It is stated that by this process a single print can be produced, including the developing, fixing, washing and drying, in 2½ minutes from a pencil drawing, and that where the work is done in quantities, 60 or more prints may be made in an hour. The drawings to be reproduced should be finished with a firm line such as is produced by an HH pencil. The largest print the apparatus will make is 14 by 11½ inches. The process may also be used for copying tracings, printed matter, deeds, documents, letters, or even blue-prints, of which good copies can be made by the use of a color screen which forms a part of the apparatus.—Condensed from *The Engineer*.

The Principles of Fuel Oil Engines—I*

The Chemical and Physical Basis of Their Operation

By C. F. Hirshfeld

It is not the intention of this paper to consider the various real liquid fuel engines nor to discuss the weak and strong points of such engines as have already been constructed. I have taken a different method of attack and, going back to first principles, have attempted to analyze the different phenomena which enter and to draw conclusions therefrom.

Doubtless much that I say will prove to be already known to many, but I hope that the orderly arrangement and the co-relating of such knowledge may prove worth while. Personal experience has shown me that this is the only way in which the many apparently contradictory phenomena met in liquid fuel engines can be properly appreciated.

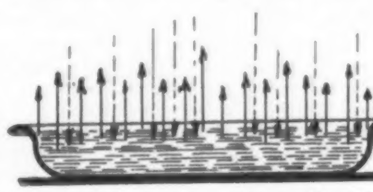


Fig. 1a.—Evaporation and recondensation.

We will first review certain simple physical phenomena which may seem to have little connection with our subject, but it will be discovered later that they are all-important.

There is considerable misunderstanding of the phenomena known as evaporation, vaporization, and boiling, largely because of a loose use of the terms. It is first necessary to clear up this part of the field and for this purpose we will start with Fig. 1*a*.

It is a matter of common experience that water, placed in an open vessel, such as that shown in Fig. 1*a*, and left exposed to the atmosphere, will gradually disappear. We explain this by saying that the water evaporates.

Actually, if we take the kinetic view of matter, the molecules of the liquid water are in rapid motion and whenever one of these happens to strike the surface under conditions which permit it to penetrate it will do so and pass off into the space above. The full arrows in the figure are supposed to show how the molecules leave the surface and gradually dissipate in the space above, that is, how evaporation occurs.

If any water molecules, traveling in the space above the liquid surface, happen to strike that surface under conditions which will permit them to penetrate they will do so and thus become part of the liquid. Such action is what we commonly call condensation and is illustrated in the figure by the dotted arrows.

In general, under such conditions as we have assumed, the molecules leaving the liquid will greatly outnumber those entering and therefore the water will gradually disappear or evaporate. Observe, however, that evaporation and condensation really go on at the same time, and it is the relative value of the two phenomena which determines whether the liquid present increases or decreases in quantity.

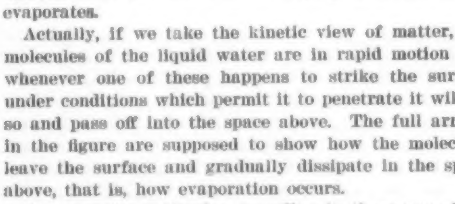


Fig. 1b.—Liquid and vapor in equilibrium.

Taking one step more, experience shows us that the higher the temperature of the liquid exposed the more rapidly will it evaporate. This simply means that the liquid molecules are moving faster at the higher temperature, more of them arrive at and penetrate the liquid surface in a given time, and hence more escape.

If the space above the liquid be also at a high temperature, the chances of these molecules getting far from the liquid surface are great; if the temperature above be low, the chances for a large number returning are increased.

If the atmosphere above the liquid is moving across the liquid surface (a wind) the molecules leaving will, in general, be carried away before any of them have had a chance to return to the liquid and evaporation will be increased.

Let us now take the arrangement shown in Fig. 1*b*. This represents the same vessel of water with a bell jar placed over it so as to inclose the space above the liquid. It is obvious that if we have enough water to start with, it will only be a matter of time before just as many molecules are returning to the liquid as are leaving it in a given time. That is, eventually the space above the surface will contain so many molecules of water that condensation will equal evaporation, and we would say in our approximate way that evaporation had ceased.

When this sort of equilibrium is reached we say that the space is saturated with the vapor of water, which really means that the space is filled with the saturated vapor of water.

Suppose, now, that we try an experiment with this apparatus. We will first maintain the whole thing at

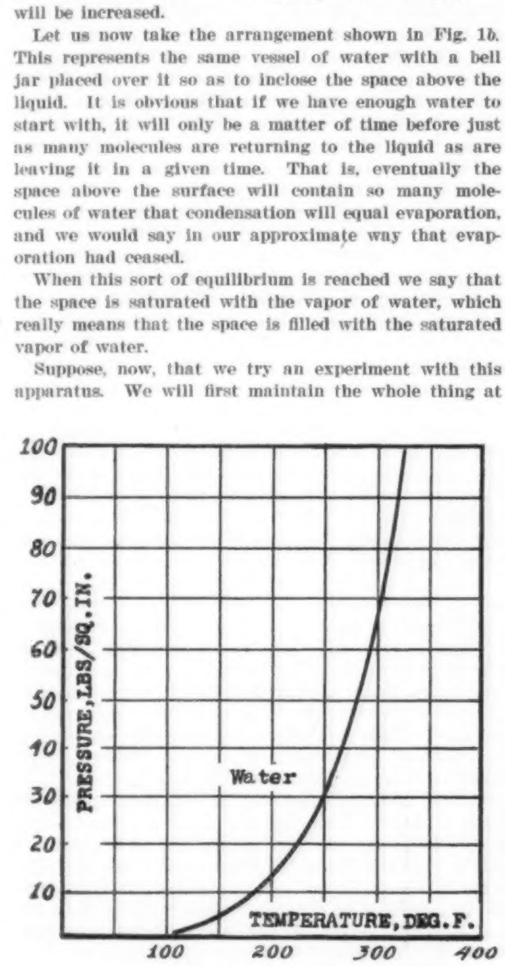


Fig. 1c.—Vapor-pressure curve of water.

some definite temperature and observe the level attained by the liquid after equilibrium is reached. We will then maintain the whole apparatus at successively higher temperatures and observe the levels attained in each case. Our observations would show that the higher the temperature the lower the level of the water in the vessel when equilibrium is reached or, the higher the temperature, the more molecules exist in the space above the liquid when saturated conditions are reached.

But we know that the more molecules we pack into a given space the greater is the pressure exerted by those molecules since more of them must strike the walls in a given period of time. It follows directly that the saturated vapor will exert greater pressure the higher its temperature.

This is a matter of common knowledge among engineers who know that steam pressure, i. e., the pressure of saturated water vapor, increases with the temperature. This is shown graphically in Fig. 1*c* which was plotted from the data given in an ordinary steam table.

While we are accustomed to speak of steam pressures at different temperatures what we really mean are the pressures of saturated water vapor at those temperatures or, in the words of the physicist, the vapor pressures of water.

It would, of course, make no difference in our reasoning if we substituted some other liquid for the water we have been discussing. We might, for instance, have used absolute ethyl alcohol, liquid hexane, liquid benzene, or any other material which is a liquid under the conditions of our experiment. Had we used such liquids as those mentioned we should have obtained results similar to those shown graphically in Fig. 1*d*. These curves were plotted from the vapor tables of the various liquids in question just as the previous curve was plotted from the steam table.

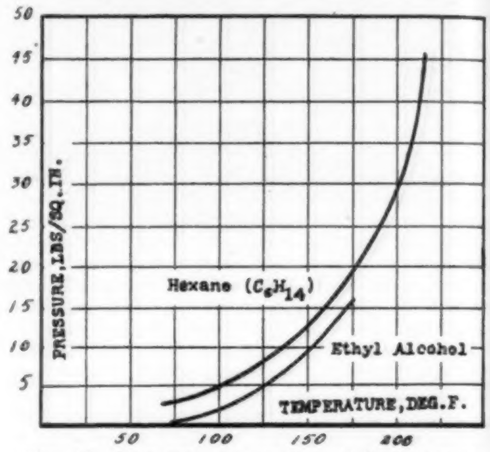


Fig. 1d.—Vapor-pressure curves of hexane and alcohol.

Assume now that we vary our experiment by introducing a pump which will circulate the water, as shown in Fig. 1*e*, so that we maintain a shower of drops falling into the liquid through the space above it. It is obvious that we expose much more surface of liquid than in the previous arrangement and therefore more molecules will escape in a given time. Hence we will fill the space more rapidly and reach equilibrium conditions more quickly. After equilibrium is attained, condensation on the surface of the drops and of the liquid in the vessel must equal the evaporation from those surfaces.

It is also obvious that the smaller we make the drops, that is, the finer we spray, the more quickly will we reach equilibrium conditions. If we could spray so finely as to introduce single, separated molecules instead of drops of finite size, equilibrium would be attained almost instantaneously if we could pump fast enough.

But before we had reduced the drops to any such small dimensions we should have met another phenomenon. We should have discovered that the small drops did not immediately descend to the liquid in the vessel but remained floating in the form of fog. Under such conditions we could get a space saturated with the vapor and also filled with floating drops of the liquid. Such conditions are often described by saying that the space is supersaturated, but this is a very loose use of the word.

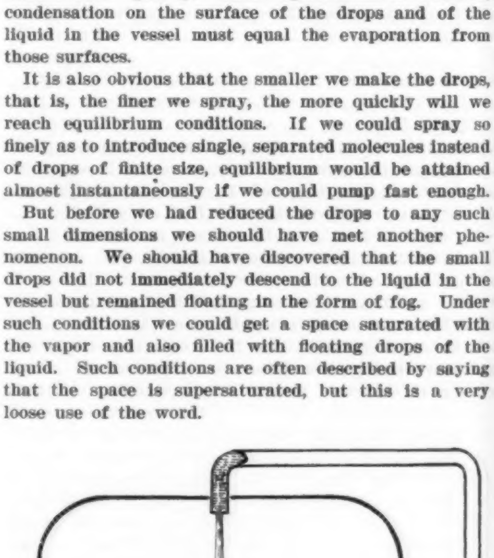


Fig. 1e.—A spray hastens establishment of equilibrium.

If we heated the space thus supersaturated the number of molecules required to saturate it would increase and consequently our finite drops would gradually evaporate and disappear. On the other hand, if we lowered the temperature some of the vapor molecules

* Paper read before the American Society of Agricultural Engineers, and published in the *Gas Review*.

would separate out, that is condense, upon the liquid surfaces. Some would enter the surface in the vessel, but more would enter the surfaces of the drops in the space above. If the temperature were lowered to a sufficient extent the drops could thus be made so heavy that they would no longer float, but would descend in a rain exactly like the rain which descends upon the earth.

Thus far we have said nothing about air within the bell jar though in any real case, had we performed the experiment as indicated, there would have been air present. We said nothing about it for the simple reason that its presence or absence makes no difference in the phenomena we have been discussing. We need consider temperature, and temperature only, for it is temperature alone which determines the number of molecules of any substance required to saturate a given space, and it is temperature alone which determines the pressure which those molecules (the vapor) are going to exert.

If air, or any similar neutral gas, happens to be present it will exert a pressure on the walls which bound the space, but, so far as the vapor is concerned, it might as well be absent. The vapor will exert the same pressure on the walls whether the air is there or not. The pressure recorded by the walls, however, will always be the combined pressure of air and vapor, that is, the sum of the two which are therefore called the partial pressures.

We can sum this up very simply by saying that so far as the vapor molecules and their motions are concerned the presence of the air molecules has no effect. It should, however, be observed that if two sets of molecules occupy the same space they must eventually acquire the same temperature, and that this may in some cases lead to apparent contradictions of the previous statements.

There is one more fact about evaporation which should be noted. If we consider once more the apparatus in Fig. 1*b* it is easy to prove that when we first put the bell jar over the vessel the rate at which the liquid surface is lowered by evaporation will be greatest and that it must decrease until it becomes zero when the saturated condition is reached. To prove this it is merely necessary to note that when the experiment starts there will be no molecules returning (assuming absolutely dry air) and that the number returning must grow greater until the saturated condition is attained.

Summing up what has preceded, we have discovered:

1. Evaporation and condensation occur simultaneously.
2. The apparent effect is merely the net result.
3. Increase of temperature of liquid and motion of the atmosphere will increase net evaporation.
4. A space is saturated with vapor when it contains so many molecules of that vapor that evaporation and condensation are equal.
5. The number of molecules required to saturate increases with temperature, so high temperature space holds more weight than low temperature space.
6. This gives increasing pressure with increasing temperature, that is, vapor pressure increases with temperature.
7. A space may hold more than the amount required to saturate it if the excess exists as fog.
8. These phenomena are independent of any material which is inert with respect to the vapor under consideration.
9. The pressure of vapor in confined space is dependent only on temperature if it is saturated, but pressure registered by walls is total or sum of all pressures within space.
10. Net evaporation is most rapid when space is farthest from saturated condition, less rapid the nearer saturation is approached.

Let us now consider boiling in order to discover how it is related to evaporation. In the cases already considered we found that the presence of air had no effect. The molecules of water might therefore be pictured as penetrating the spaces between the molecules of the air just as though the latter were not present. We also discovered that raising the temperature would also increase the pressure of the saturated vapor, that is, the vapor pressure.

Let us now imagine the vessel shown in Fig. 1*a* to contain water and to be exposed to the air as before. The pressure on the surface of this liquid is undoubtedly that of the atmosphere which we will assume as the standard 14.7 pounds for convenience. Experience shows us that if we raise the temperature of the water to 212 deg. Fahr. what we call boiling will occur; that is, bubbles of vapor will form within the liquid, pass out, and disappear into the space above.

If you consult the steam tables or the curve shown in Fig. 1*c* you will discover that the pressure of saturated water vapor at 212 deg. Fahr. is 14.7 pounds, that is, it is equal to that of the atmosphere under the assumed conditions. It is evident, therefore, that what we call boiling or ebullition occurs when the temperature of the liquid has the value at which its vapor exerts a pressure equal to that upon the surface of the liquid.

As a matter of fact, the temperature of the molecules forming any particular bubble must be slightly higher than this in order that they may be able to push away the water as they form a bubble under the superincumbent pressure plus the head of water under which they exist. The rising of the bubble is due to its lower density with respect to the surrounding water; it is literally pushed out into the atmosphere by the surrounding water. As soon as it enters the air it begins to break up, that is, the individual molecules each go their own way or diffusion occurs.

Boiling or ebullition is, then, merely a very rapid form of evaporation which occurs when the vapor pressure equals that on the liquid surface. Under these conditions molecules can push themselves out in groups instead of having to thread their way singly between the molecules of the superincumbent gas.

Suppose now that we change things slightly and produce a rain of drops of liquid at boiling temperature. Each drop is in such a condition that all of its surface can immediately flash into vapor and, if we assume a sufficient heat supply available, there is no reason why the entire drop should not become a vapor and diffuse into the surrounding atmosphere. Such action would, of course, cease when we attained a saturated atmosphere since condensation would then be as rapid as vaporization. In other words, we have merely devised a means of expediting evaporation beyond what was possible with previous arrangements.

The same result can be achieved in another way. We might devise a means of suspending small drops of liquid in air and then heat both the air and the drops. Evaporation would result, and if we heated rapidly enough we might attain boiling temperature and get the same phenomena as before. If we heated slowly we might attain saturated conditions before boiling temperature was reached.

We have now considered processes of various kinds which show that what we call ebullition or boiling is merely a sort of limiting case of evaporation.

In all of the preceding we have entirely omitted any discussion of heat supply, assuming conveniently that such heat as might be required would be forthcoming. Actually, it requires very large amounts of heat to produce the evaporative results we have been considering. In the case of water the quantity is in the neighborhood of 1,000 British thermal units per pound; in the case of gasoline it is about 100 British thermal units, and in the case of alcohol (ethyl) in the neighborhood of 400 British thermal units.

If this heat is not supplied from some external source it will be taken from the vaporizing liquid itself and from the air and apparatus.

(*To be continued.*)

The Uses of Artificial Insulating Materials in the Construction of Electrical Apparatus*

By H. Passavant

The four most essential properties of an insulating material may be stated as follows: (1) It must possess great mechanical toughness, so that if made in a suitable shape it can resist the unavoidable shocks of everyday work. (2) It must be capable to some extent of resisting the effects of heat, so that an accidental rise of temperature is not accompanied by any serious disintegration. (3) It must be capable of resisting the action of fire to such an extent that it is very little damaged, and should be able to withstand the action of an arc; after such exposure to flame, it should not be found to have lost its insulating or mechanical properties. (4) It should, to a sufficient extent, be able to resist the effects of moisture or chemical action, at any rate to such an extent as would be likely to be necessary in actual working. A commission has lately been engaged in investigating the properties of insulators, and it may be of interest to discuss some of the points which have arisen in connection with that work.

If a piece of "Tenacit" of the kind that was made a few years ago is held in the Bunsen flame the flame soon becomes colored and the material appears to catch fire after a short time; but as soon as the flame is removed, the tenacit ceases to burn. With a piece, exactly similar, but of the latest manufacture, these effects take place much more slowly, and it is extremely difficult to inflame the material at all; after removal of the flame the piece is found to be practically uninjured. If a plate of tenacit 10 millimeters thick is taken, and some thermit is placed on it and inflamed, causing a temperature of 2,500 deg. Cent. or 3,000 deg. Cent., a lightly burnt spot will be noticed; but if the burnt surface is scratched away it will be found that the burning is only superficial, and that the rest of the material is quite uninjured. The electric arc must be taken into account as a disturbing influence in considering insulating materials, for it may be liable to be exposed to such an accident at any time. If the different materials are tested by exposing them to an arc of 10 amperes at 220 volts between carbon electrodes, the arc being gradually drawn out to its greatest length, very different results are given by different materials. Thus marble tends to extinguish the arc; the electrodes can only be drawn out on the surface of the marble to a length of about 2 centimeters, when the arc is extinguished. Slate is easily fused by the arc without becoming a conductor. The arc cannot be drawn out to a greater length than 4 centimeters. Inflammable materials are naturally set on fire, and conductive surfaces are therefore formed by the carbonization of the material, and the arc can therefore be drawn out to considerable lengths. Many substances that cannot be inflamed by an ordinary burner become inflammable in the arc and burn with a sooty flame; and in this case the electrodes can be drawn out to a distance of about 12 centimeters. Tenacit of the latest type cannot be set on fire by the arc, and even after a length of time there is no soot formed. It only becomes conductive when fused and heated to a bright red heat, but the arc can then only be maintained over slightly greater lengths than in air. A really good insulating material differs from porcelain and substances such as those used in the Nernst lamp, which become conductors at high temperatures and help to maintain the arc instead of suppressing it. With respect to chemical inactivity, it is not possible to lay down very stringent conditions; it is generally sufficient if the substance is able to withstand the effects of wind and weather, including snow, ice, and the light of the sun. Such a condition is not difficult to fulfil. It is rather different from an order which was lately received and executed by the Allgemeine Elektrizitäts Gesellschaft for a vessel made of insulating material to hold electrolytic chlorine; the said vessel was delivered and has been working satisfactorily for a long time. The following experiment will help to give some idea of the toughness of tenacit. Suppose a plate of cast iron 3 millimeters thick to be placed on a layer of sand, and also a similar plate of tenacit. If now a steel ball weighing ½ killigramme is allowed to fall on them from a height of about 1 meter, the tenacit plate will be broken or cracked, w ereas the cast-iron one will remain uninjured. Suppose the tenacit plate to be replaced by another, having the same weight as the cast-iron one, and the experiment to be continued. It will then be found that the cast-iron will be shattered when the ball falls from a height of about 1.5 meters, whereas this will not take place with the tenacit until a height of about 2 meters is allowed for the fall. Naturally this proves nothing as to the relative strengths of the two materials, but it may help to give some sort of rough idea as to the toughness of the present manufacture.

These artificial insulating materials are used for many purposes, principally perhaps for small pieces of apparatus used in an ordinary house, or in

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small workshops where no sort of skilled supervision is possible. Thus, in Berlin alone there are in actual use some 45,000 meters, which stand on bases made of artificial insulating material, which is sufficiently damp-proof and heat-proof to suit the circumstances, and is also sufficiently plastic to be molded to the required shape. There is also a field in connection with electric heating a paratus. The new insulating materials can be used luckily to insulate either the electric current or heat; used as a heat-insulating medium, they serve to limit and confine the heat in any way that may be desired. Thus, in connection with workshop processes, where, as in certain paper-making methods, heat is necessary locally, it may be highly desirable on economic grounds to "insulate" the heat; in other words, it may be necessary to heat the paper locally without any intention of heating the atmosphere generally. In a particular case of this kind, by a proper adjustment of the apparatus and the use of a proper insulating material in its construction, it became possible to effect a reduction of 20 per cent in the annual cost for energy. Water-heating apparatus of the electric kind has lately absorbed a good deal of attention, and here again something can be done on similar lines, seeing that the essence of success lies in the possibility of insulating the heated water from the surrounding atmosphere. There is thus a large field for the application of these substances in the capacity of heat insulators which is probably almost as extensive as that in which they figure as electric insulators.

But it is, perhaps, as well to address a word of warning to manufacturers. Not long ago it was considered to be sufficient to state in public advertisement that the insulating material which was commended to the public was able in such and such a thickness to withstand the attack of so many thousand volts, while the insulation resistance amounted to several thousands of megohms. If a lighted match was held in contact with the substance in question, it was generally found that all this was vain boasting; all the other conditions which a successful insulator must possess seemed to have been left out of account. This, of course, refers to the state of the art as it was a few years ago, and the facts which have been stated about tenacit and the arc serve to show the progress that has been made. The "ageing" of the material must also be considered, especially if it contains organic material, and a neglect of this consideration has also led to much disappointment. Makers must be prepared to give much more stringent guarantees than in the past, and the plastic materials, which are more and more coming to the front, must have their properties well defined and easily understood.

Various substances of this nature are made, several of them in different grades. Thus, tenacit is made in six grades, the minimum thickness of the different grades varying from 2 to 5 millimeters. It varies in color from white to black, and is used for meter bases, overhead equipments, handles, covers and various kinds of electrical apparatus; it is also said to be used for making the steering wheels of motor cars. Its properties, as well as those of the other substances hereafter mentioned, are given relatively and roughly in the form of figures under the following headings, each for the different grade, viz., hardness, toughness, insulating capacity, heat-resisting powers, and the power to resist damp and chemical action. The next substance is vulcanite in four different grades with a minimum thickness varying from 2 to 0.2 millimeter. It is mostly used for shaped articles of various kinds. Then comes stabilit, with a minimum thickness varying from 2 to 1 millimeter. It is made in five grades, and varies according to the grade from brown to black and red. It is also largely used for shaped articles. Then there is "iron vulcanite" in three grades with a minimum thickness between 2 and 1 millimeter. It is gray in color. It is used in overhead equipment, and for ship and carriage work. Then there is vulcanized asbestos of a minimum thickness of 2 millimeters, grey in color, used for coils, bushes, disks, switches, etc. And finally, vulcanized fiber of a minimum thickness of 1 millimeter, used for bushes, disks and plates, red or black in color. The figures which represent the properties of the various substances are stated on the authority of the commission which has been investigating the matter of insulators. It is probable that a substance like tenacit will in the not distant future be manufactured in far fewer grades than at present, and this would seem to be desirable on many grounds. It will, however, before long be almost impossible to find a switch handle constructed of such an insulating material that it inflames and almost explodes as soon as a match is held to it; and yet cases of this kind can be found at the present moment.

The Mechanical Design of Switches*

ELECTRIC driving of mechanical engineering works, generally by direct current, is now almost universal, and even a moderate-sized works may have in its equipment several hundred motors, supplying power for the large machines independently, the smaller ones in groups, and the various auxiliaries, such as cranes, air compressions, pumps, etc. Each of these motors is controlled by its own starting and operating switches, which are at the mercy of the men working the machines, who do not understand them and cannot be expected to appreciate their niceties. It is, therefore, surprising that the design of the majority of switches is still mechanically so imperfect, when the treatment they are likely to receive is considered. Improvements constantly tend in the direction of making them electrically rather than mechanically fool proof; but this tendency is bound to lead to increased complications and therefore increased possibilities of mechanical breakdown.

In the most common type of starting switches, viz., the flat-segment type, the contacts and contact arm are mounted on a slate, marble, or composition base, and owing to the hard and non-resilient nature of these substances, it is difficult to prevent the small nuts and screws fixing the moving parts from becoming loose under the continuous rough usage to which the switch is subject; moreover, if it is of the open type most of the wear and tear is taken entirely by the base. In this respect the ironclad or protected type has the advantage, as the casing relieves the base of the mechanical strains; but this type is less accessible for repairs and is very heavy to take down and replace.

The chief fault of this simple starting switch is that it is easy to operate it too rapidly. This difficulty has been overcome in one design by moving the contact arm indirectly through a worm reducing gear by means of a second shaft to which the handle is connected. This is, on paper, an excellent idea, but practically the worm and worm wheel are not made nearly robust enough and consequently both are soon stripped. Another disadvantage is that the arrangements for holding the handle or worm in gear when starting, and releasing them when the arm is full over, are not satisfactory. In order to stop the motor and return the arm to the starting position, a neat little button is provided to short-circuit the no-volt coil; often, however, the arm sticks and will not release itself, and as it cannot be "assisted" from outside the casing, banging and jolting are resorted to until it goes back.

When overload releases are fitted they are also a source of weakness. Their parts are generally small; and, as they ought to go for months without operating, they are liable to get stuck, owing to gummy oil and grit in the joints of their mechanism. When a short does occur, and it is essential that they should act, they cannot be depended upon to operate within 50 per cent, or even 100 per cent of the current set for; and since they usually cut out by short-circuiting the no-volt coil, they are open to the same objection as the push-button for stopping.

The strongest and most reliable controller is the drum type universally used for service motors on traction work and cranes. The drum is well supported and protected from mechanical damage by the very rigid casing. Unless, however, the "notching" gear and spring are amply strong and well designed, it is possible to stop the drum between notches, causing much damage to the fingers through continual arcing. The advantages of this type as regards durability are becoming more widely appreciated, and a modified form, the pillar-type controller, is being increasingly used for machine-tool motors.

Another point which, though not strictly concerned with mechanical design, might be noted, is that it is absolutely essential that proper "inching gear" should be provided for obtaining the very small movements often required when setting machines or taking out work. It should be possible to obtain just as small a movement with the machine light as when it is fully loaded.

Main switches with intricate toggle joints are liable to give trouble when the joint-pins begin to wear; this occurs fairly quickly, as they are generally too small and do not receive much attention in the way of lubrication. It is, however, scarcely possible to avoid these joints when heavy currents have to be broken by trip-gear incorporated with the switch.

Although, therefore, the "fool-proof" ideal appears attractive, advances in this direction can usually be obtained only at a sacrifice of mechanical simplicity, and this sacrifice is often too great. When the time lost during the course of a year through continual small delays caused by defects in switches is considered, it pays the user to insist on ample strength and simple design, thus insuring that, instead of being generally defective, they will always be in good order. Reliance will have to be placed for protection from damage on fuses only, but these cannot easily go wrong, and wilful tampering can be avoided by inforcing severe penalties and by placing them under lock and key. It must be constantly borne in mind that the machinist regards his switches more or less in the same light as he regards his spanners, and treats them with about the same amount of consideration. Any extra expense to the user on heavier switches is likely to be amply repaid by reduction of lost time and of repair costs.

* Reproduced from *The Electrical Review*.

A Magnetic Expedition to Hudson Bay, under Dr. H. M. W. Edmonds, sent out by the Department of Terrestrial Magnetism of the Carnegie Institution, is spending the period from May to October in securing data from the region between the Albany and the Severn rivers, with a special view to locating, as accurately as possible, the focus of maximum total intensity in North America.

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